APPENDIX A

ROADMAP PARTICIPANTS AND ORGANIZATION

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ROADMAP PARTICIPANTS

The Roadmap employed a multidisciplinary team 38 subject matter experts organized into four workgroups and a Roadmap Executive Committee.

Executive Committee Members

LTS Science and Technology Roadmap Board of Directors

- Edwin L. (Larry) Davis, Chair – President, BWXT Savannah River Company
- George Apostolakis – Massachusetts Institute of Technology
- J. Lane Butler – Kaiser-Hill Company, LLC
- Shah Choudhury – U.S. Department of Defense Environmental Cleanup
- Lorne G. Everett – Shaw Environmental and Infrastructure
- Howard Roitman – Colorado Dept. of Public Health and Environment
- James Woolford – U.S. Environmental Protection Agency
- Clay Nichols – U.S. Dept. of Energy-Idaho Operations Office
- Bruce Hallbert – Idaho National Engineering and Environmental Laboratory

LTS S&T Roadmap Steering Committee / Work Group Chairs

- David J. Borns – Monitoring and Sensors - Sandia National Laboratory
- James H. Clarke – Contamination Containment and Control – Vanderbilt University
- William R. Freudenburg – Decision Making and Institutional Performance - University of California at Santa Barbara
- James V. Mohat – Safety Systems and Institutional Controls - JVM and Associates

Workgroup Members

Contamination Containment and Control

- Doug Burns – Idaho National Engineering and Environmental Laboratory
- Jeff Dunn – Kleinfelder, Inc.
- Margaret MacDonell – Argonne National Laboratory
- Ellen Smith – Oak Ridge National Laboratory
- Robert Waters – Sandia National Laboratory
- Jody Waugh – MACTEC-ERS

Monitoring and Sensors Workgroup

- Chris Beck – Project Enhancement Corporation
- Dawn Kaback – Concurrent Technologies Corporation
- Horace Moo-Young – Lehigh University/EPA Research Fellow
- Bridget Scanlon – University of Texas
- Mike Serrato – Savannah River Site
- Everett Springer – Los Alamos National Laboratory
- Ron Wilhelm – Environmental Protection Agency

Decision Making and Institutional Performance

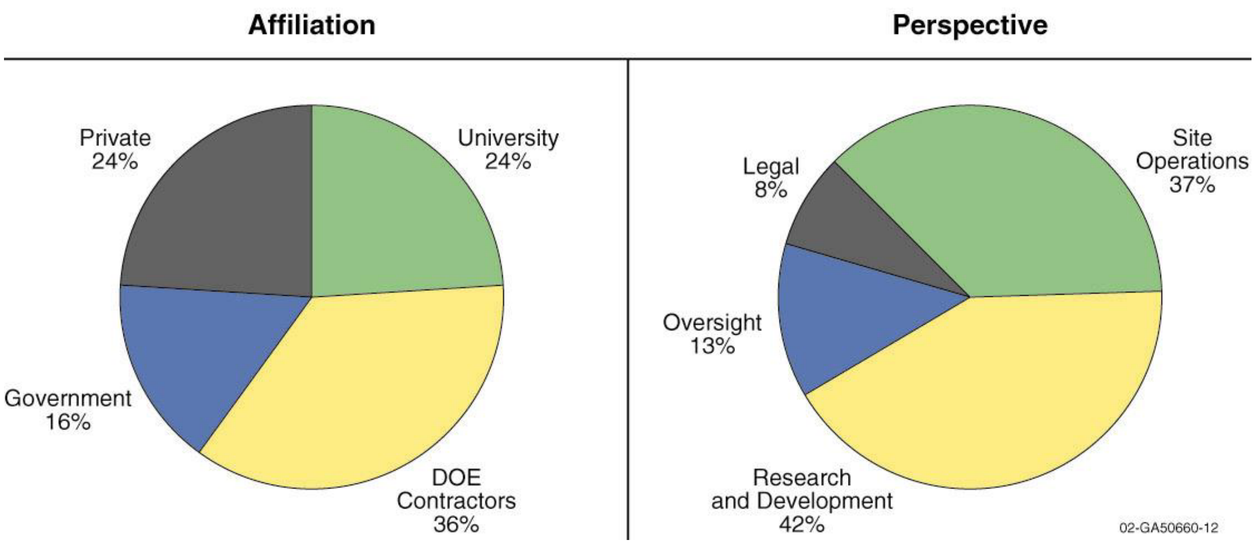
- Lee Clarke – Rutgers University
- Kai Erikson – Yale University (Retired)
- Deborah Griswold – DOE Albuquerque Operations Office
- Elizabeth Hocking – Argonne National Laboratory
- Thomas Leschine – University of Washington
- Thomas Marshall – Rocky Mountain Peace and Justice Center (former member of the Rocky Flats SSAB)

Safety Systems and Institutional Controls

- Norman Brandon – Creative Concepts
- David French – Aspen Resources
- David Johnson – University of Oklahoma
- Donald Paine – Nuclear Fuel Services, Inc. (Fernald)
- Kimberly Peone – Critical Data Tribal, LLC
- Darby Stapp – Pacific Northwest National Laboratory

Participant Affiliation and Perspective

The composition of participants is as follows:



Technical Contributors

Contamination Containment and Control

- Wendy Cain – DOE-Oak Ridge Office
- Ken Cook – Bechtel Jacobs
- Tom Early – Oak Ridge National Laboratory Environmental Sciences Division
- Mark A. Gage – Bechtel Jacobs (Paducah)
- Sid Garland – Bechtel Jacobs (Planning Group)
- Jim Hart – DOE- Oak Ridge Office
- Janice Hensley – Bechtel Jacobs (Y-12 National Security Site)
- Phil Jardine – Oak Ridge National Laboratory Environmental Sciences Division
- Daniel S. Jones – Oak Ridge National Laboratory Environmental Sciences Division
- Cynthia Kendrick – Oak Ridge National Laboratory, Director of Environmental Technology Programs
- Dick Ketelle – Bechtel Jacobs
- Paula G. Kirk – Bechtel Jacobs
- John Kubarewicz – Bechtel Jacobs, Manager of a technical integration group connected to EM project management. (Developed LTS cost estimates for ORO EM life-cycle baseline for five DOE sites and provided extensive information about LTS cost estimates, including assumptions used in developing them).
- John A. Lea – Bechtel Jacobs (K-25 Site, Project Management)
- Jack Parker – Oak Ridge National Laboratory Environmental Sciences Division
- Elizabeth Phillips – DOE- Oak Ridge Office/EM, SCFA DNAPL Product Line Manager
- Craig Rightmire – Bechtel Jacobs
- Ralph Skinner – DOE- Oak Ridge Office Long-Term Stewardship Coordinator
- David Starling – Bechtel Jacobs
- Robert Washington-Allen – Oak Ridge National Laboratory Environmental Sciences Division ecologist

Safety Systems and Institutional Controls

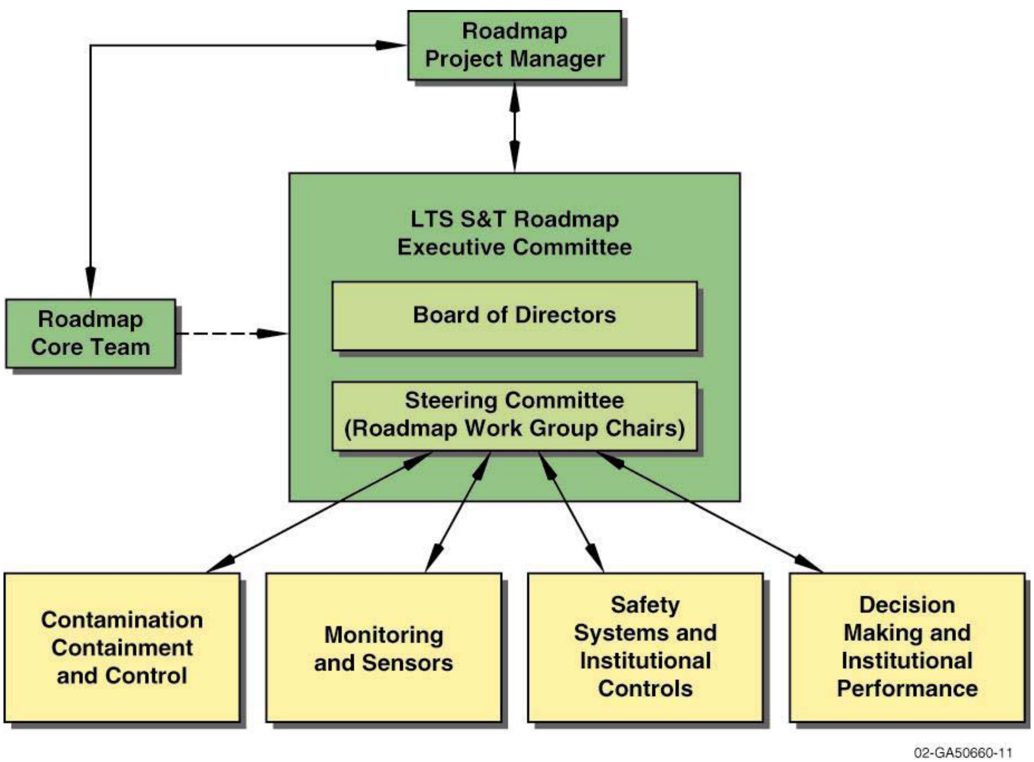
- BIOS International Corporation (Sentry type sensor technology)
- Gary M. Bratt, Ph.D.,PE.,DEE,CIH – Research Fellow, Logistics Management Institute (Environmental Health Engineering)
- Ted Finucane, PE,CSP ,CIH – Hi-Tech Enteprizes, Inc. (Sensor and monitor application)
- NITON, BDC (Remote Controlled Monitors/Analyzers)

ROADMAP ORGANIZATION

Specific elements key to the success of the Roadmap Project include the organizational structure (including the Roadmap Executive Committee and Workgroups), as well as the workshops necessary to develop a sound S&T investment strategy for the DOE.

Organizational Structure

Based on the objectives of the Roadmap, EM draft roadmapping guidance, and lessons learned from previous roadmapping efforts, an organizational structure was established to promote the broad participation and collaboration of interested and effected parties. The Roadmap Executive Committee was delegated leadership of the Roadmap effort as defined and bounded by DOE. A Roadmap Core Team, composed of INEEL staff reporting to the Roadmap Manager, supported the Roadmap Executive Committee. Roadmap Workgroups were responsible for investigating various S&T issues associated with the Roadmap and for developing the Roadmap text for their respective topical area.



Roadmap Manager

The Roadmap Manager was responsible for the quality of the Roadmap products and for delivery of the Roadmap to DOE. As such, the Roadmap Manager reviewed the technical, administrative, managerial, and budgetary targets of the Roadmapping effort and took appropriate actions to ensure progress toward achieving them. The Roadmap Manager and the Roadmap Executive Committee provided a communication channel with DOE and INEEL management, regulators, site contractors, and other stakeholders.

Roadmap Executive Committee

The Roadmap Executive Committee was delegated leadership of the Roadmap effort as defined and bounded by DOE. The Roadmap Executive Committee was composed of a Board of Directors and a Steering Committee of Roadmap Workgroup Chairs, as described below.

Roadmap Board of Directors

The Board of Directors directed the Roadmapping process, defined the overall technical scope of the Roadmapping effort based on collaboration from the Roadmap Manager, and ensured that all technical topics required for an integrated roadmap were covered by the Roadmap Workgroups. The Board of Directors reviewed participants selected by the Steering Committee and provided suggestions to ensure that overall work group membership reflected the broad perspectives that needed to be incorporated in this effort. The Board of Directors reviewed and commented on the major S&T objectives identified by the Roadmap Workgroups through interaction with participants during and between Roadmap meetings and workshops.

The Board of Directors was chaired by the President of the BWXT Savannah River Company, having relevant DOE site and end-user experience. The remaining directors included a site contractor operations manager, recognized S&T R&D specialists, a recognized scientist from academia, a national Environmental Protection Agency manager, a representative of the Department of Defense, and a representative from a stakeholder organization. Other members included the Chief Scientist and Assistant Manager for R&D at DOE Idaho Operations Office and the INEEL Roadmap Manager, who served as liaisons between the Roadmap Executive Committee and the DOE LTS Program Management and INEEL LTS Program, respectively.

Roadmap Steering Committee

The Steering Committee managed the Roadmap development process and ensured that schedules are met and resolved issues that arose within and between the Roadmap Workgroups.

The Steering Committee was composed of the Chairs of the Roadmap Workgroups. The Chair of each Roadmap Workgroup was a recognized authority in a respective S&T topical areas with experience in the application of R&D to cleanup issues.

Roadmap Workgroups

The Roadmap Workgroups defined the overall technical scope of the Roadmapping effort for their respective S&T topical areas. The Roadmap Workgroups drafted the major technical objectives for the Roadmap, refined objectives through interaction with the other Roadmap Workgroups, and coordinated with other Roadmap Workgroups to ensure a coherent, consistent, and reasonable Roadmap for this phase of the effort. Roadmap Workgroups were comprised of end-users from DOE field contractor organizations and industry; S&T developers from DOE national laboratories, industry, and academia; national and state regulatory agencies; and national and site stakeholder groups.

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APPENDIX B

ROADMAP DEVELOPMENT PROCESS

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ROADMAP DEVELOPMENT PROCESS AND ORGANIZATION

The scope of this Roadmap focused on improvements to near-term compliance within the DOE complex that would not alter currently established closure end-states. Follow-on phases would expand the horizon past 2012, integrate S&T initiatives by other federal agencies, incorporate technologies that could result in improved remediation designs, and coordinate S&T initiatives identified in the Vadose Zone S&T Roadmap.

A collaborative, phased approach was implemented for developing the LTS S&T Roadmap to integrate DOE's current end-state operational plans, S&T needs, and ongoing R&D. The process consisted of four major tasks: Roadmap Initiation, Technical Needs Assessment, Roadmap Development, and Roadmap Review and Implementation.

Roadmap Initiation.

The Roadmap Initiation task focused on preparation for the Roadmapping process and included obtaining agreement on the Roadmap's scope, leadership (i.e., a Roadmap Executive Committee, Roadmap Workgroups, and Roadmap Core Team), participants (including stakeholders, see Appendix A), and deliverables. Figure B-1 outlines the Roadmap Initiation process.

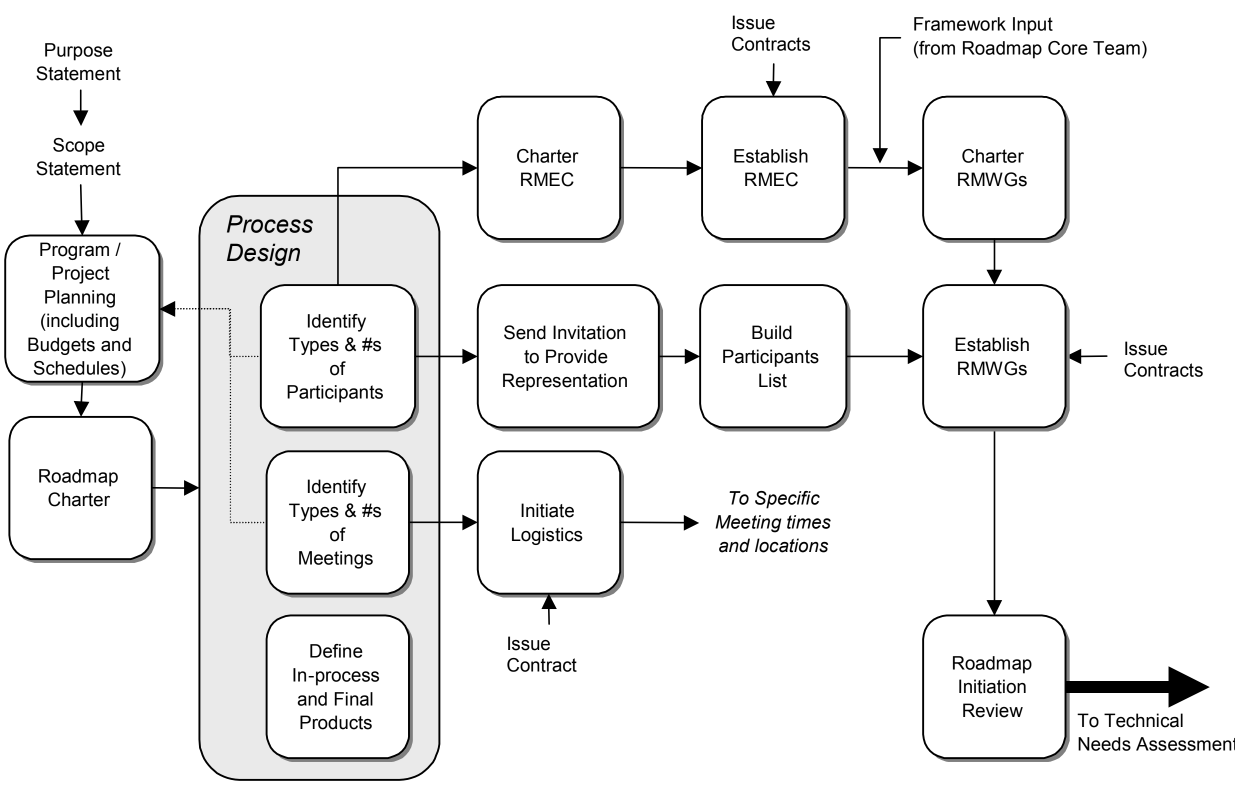

Figure B-1. Roadmap Initiation Process

Technical Needs Assessment

The Technical Needs Assessment task assessed the technical capabilities needed to achieve LTS Program goals and objectives and was a critical part of the Roadmapping effort. Needs were based on the end-state driven technologies identified as part of a Technology Profile of current DOE LTS related S&T investments for FY 2001. LTS needs were also identified by developing an Technical Baseline that complied information from many DOE sites. Representatives from LTS operations were also part of the Roadmap team, briefed the Roadmap team, and reviewed the Roadmap drafts. This task included a structured, systematic approach to identify technical issues and LTS Program functions, assess those issues and functions to identify capability and usage gaps (i.e., areas where S&T is needed to address technical issues and satisfy program functions), and establish associated program goals for S&T. The Roadmap Executive Committee directed the efforts of several workgroups in accomplishing this task (see Appendix A). A needs workshops was held to (1) define technical and programmatic needs and functions as a result of anticipated end-states and available technologies defined in the LTS Technical Baseline and Technology Profile reports, respectively, and (2) finalize objectives for the Roadmap. The workshops involved participants from regulatory agencies; state, and tribal governments; other stakeholder groups; multiple DOE sites and laboratories; other government agencies; academia; and industry. The workshops transformed issues and concerns from the participants into programmatic and technical S&T requirements. This task was completed when consensus was reached by the Roadmap Executive Committee on the programmatic and technical needs and the overall direction for the Roadmap. Figure B-2 displays the overall Technical Needs Assessment process.

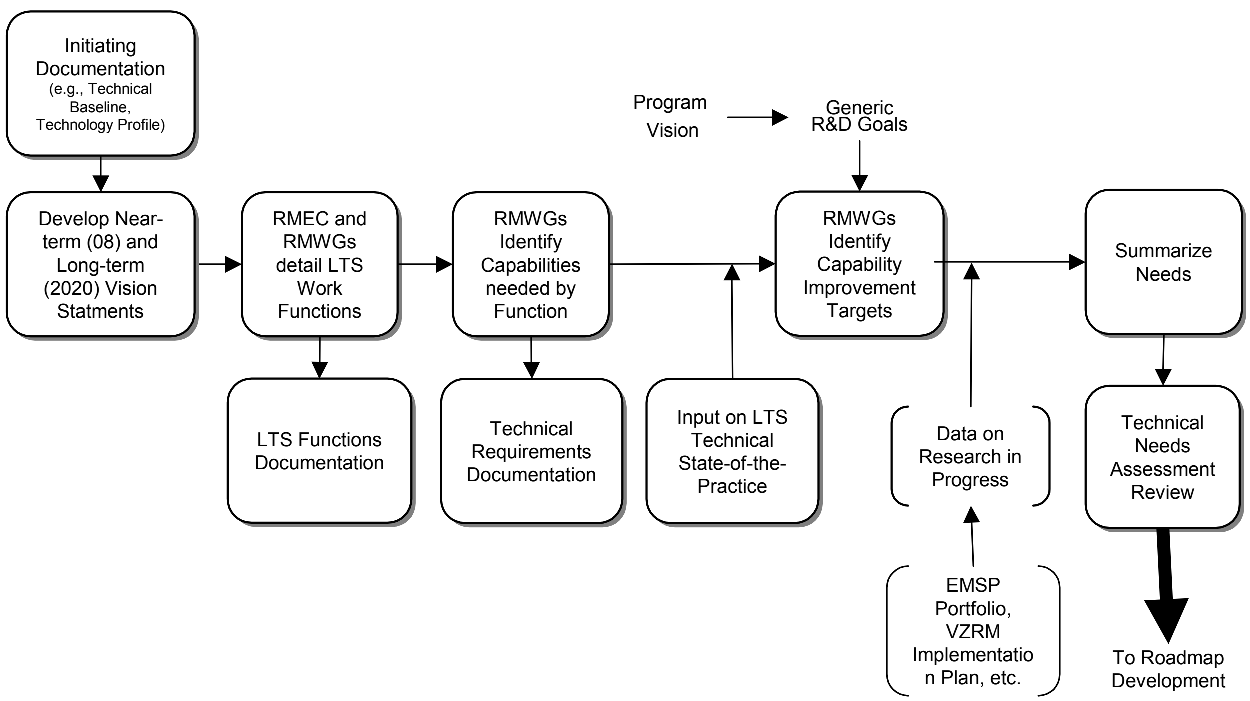

Figure B-2. Technical Needs Assessment Process

Roadmap Development

The Roadmap Development task involved identifying and documenting approaches to respond to the targets identified during the Technical Needs Assessment task and developing the draft Roadmap. Roadmap Development utilized current technology development data obtained from DOE Office of

Science and Technology (OST) Focus Areas, Environmental Management Science Program (EMSP), and Crosscut Programs, and from other government agencies to further analyze the current DOE S&T portfolio (including identified technology gaps) to aid in the development of response plans. Where Technical Needs Assessment focused on the LTS community and the R&D of technologies to provide those capabilities. During the Roadmap Development Workshop, the Roadmap Workgroups validated the gaps and targets from the Technical Needs Assessment task, identified and investigated response alternatives, and drafted response. This information was discussed by the Executive Committee at additional meetings, after which the response plans were sequenced and their associated response schedules integrated. The response plans and schedules guide S&T development such that sound investment decisions can be made. This task interfaced with other LTS teams (e.g., Information Management, Technical Baseline, Technology Profile, and Performance Assessment and Decision Analysis) and used information developed by those teams to assess the value of making various technology investments. Figure B-3 illustrates the overall Roadmap Development Process.

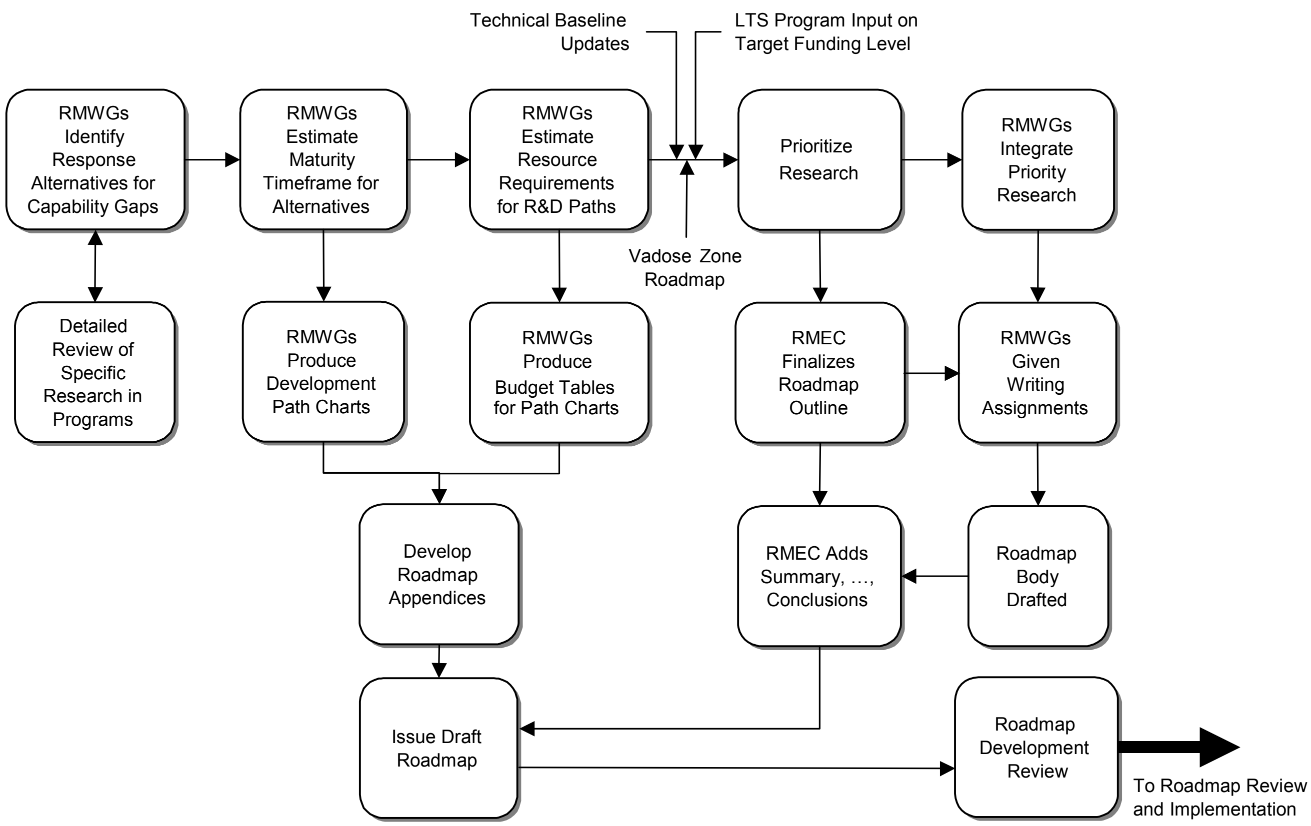

Figure B-3. Roadmap Development Process

Roadmap Review and Implementation

In the Roadmap Review and Implementation task (not yet started), the Roadmap will be reviewed, released, implemented, and updated as necessary. This task will include management briefings on the Roadmap findings, independent technical reviews, and Roadmap finalization. After release of the Roadmap, implementation plans will be developed by the Roadmap Executive Committee; R&D plans coordinated with Focus Areas, site LTS work managers, and other funding mechanisms, and R&D work plans executed to meet LTS needs. Implementation progress will be tracked and the Roadmap and associated implementation plans periodically revised and updated to support sound decision-making and ensure the timely and cost-efficient availability of S&T needs for program success. Figure B-4 shows the overall Roadmap Review and Implementation process.

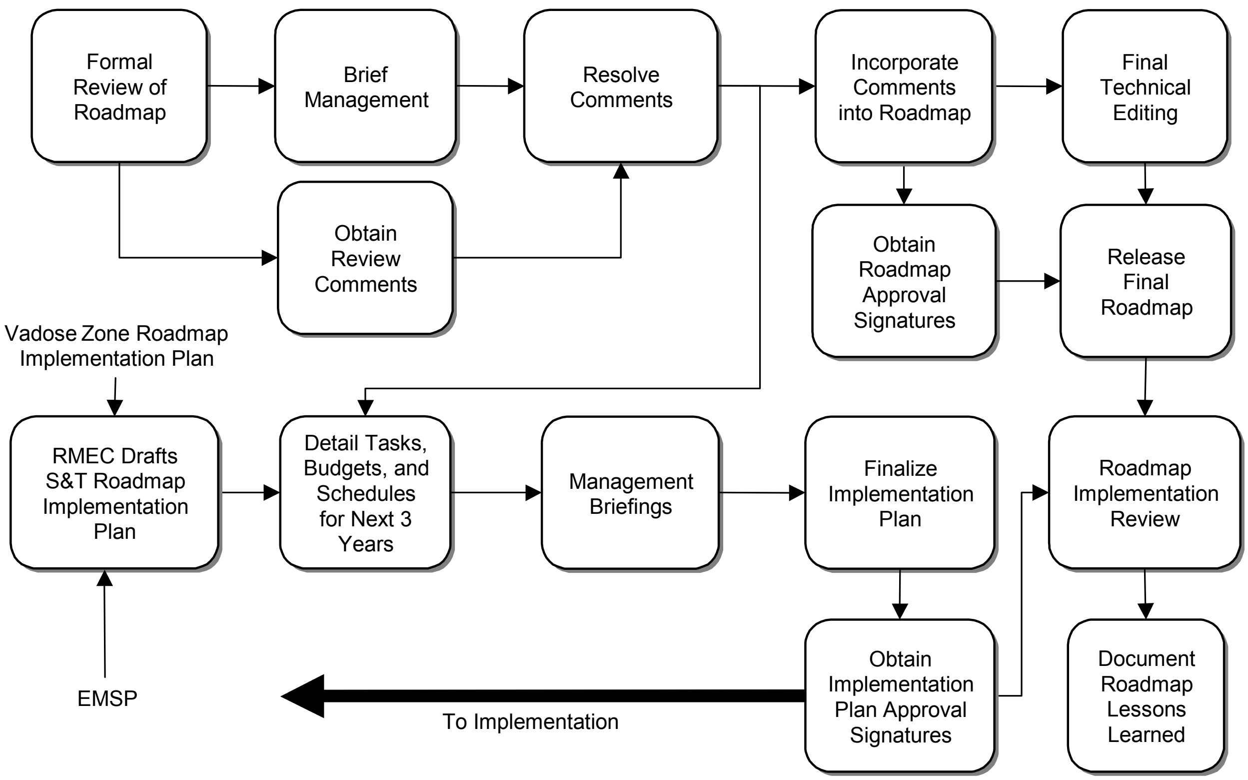

Figure B-4. Roadmap Review and Implementation Process

APPENDIX C

CAPABILITY ENHANCEMENT PATHWAYS FOR EACH TARGET

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INTRODUCTION

The Roadmap Workgroups identified general research and development pathways and associated technologies for each of the S&T targets in Chapter 2. This appendix is a compilation of that material.

The material for each target is provided in separate subsections. With a few exceptions, all sections follow the same format:

- The subsections begin with a restatement of the target text.
- This is followed by a capability enhancement pathway chart depicting how the target is to be achieved. The chart shows the general relationship of the development tasks.
- Next, each task in the pathway is described, including expected intermediate products/results, any prerequisites, and estimated duration.
- Finally, applicable technologies or techniques identified by the workgroup are documented, including their maturity level, needed R&D, and in some cases references or other additional information.

The general technology areas addressed in this Appendix comprise numerous specific technologies that are in various stages of R&D (and in some cases limited deployment for remediation). Identification of the technology-specific R&D needs and pathway for each specific technology exceeds the scope of this effort and would duplicate effort that has already been done in support of remediation. Therefore, the R&D pathways described herein are generic. Some step shown in the generic pathways can be avoided for technologies and applications that are currently under active development (see entries for "Current Maturity Level" and "Needed R&D").

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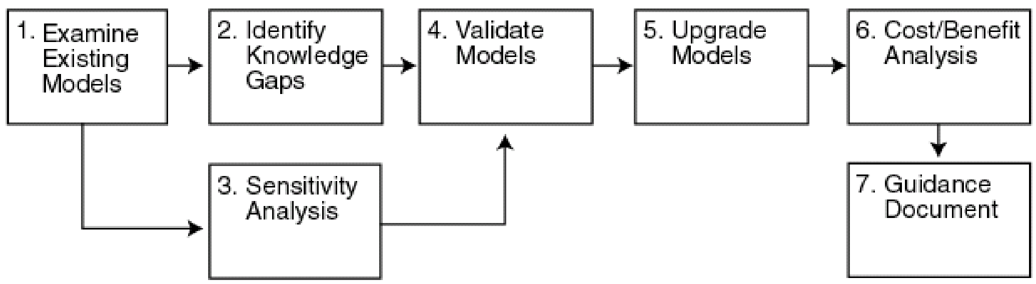
TARGET 1.1

Sites have the capability to adapt the site monitoring system based on improvements to the GHBCT conceptual model for the site.

Capability Enhancement Pathway



Pathway Task Descriptions

Task #1: Examine existing conceptual models at selected sites

Description: Collect information on conceptual models for selected sites that represent a range of GHBCT conditions and multimedia pathways. Such information includes the understanding of fate and transport, the predicted performance of the remediation system, and the GHBCT framework. Essential are identification of the performance parameters related to the remediation system based on the conceptual model and their predicted values in time if the conceptual model applies. Information on historical changes in the conceptual model will also be collected and performance data in time that may exist.

Expected Products/Results: Report detailing existing conceptual models and stages and bases.

Prerequisites: Information on current conceptual models, stages, and bases for their development for the selected sites.

Estimated Duration: 1 year

Task #2: Identify knowledge gaps

Description: Based on knowledge of current conceptual models identify gaps in the conceptual model. Examine conceptual models developed by other industries to determine gaps in conceptual models at the sites. For example the petroleum industry has been very successful in incorporating soft geologic information on depositional systems into conceptual models of oil fields to enhance production.

Expected Products/Results: Gaps in conceptual models will be identified for sites that represent different GHBCT and media.

Estimated Duration: 6 months

Task #3: Apply sensitivity analyses to conceptual models

Description: Conduct sensitivity analyses on conceptual models relative to risk and uncertainty. Sensitivity analyses will use existing numerical models developed for the selected sites. Parameters and processes will be evaluated on the basis of the greatest reduction in risk and uncertainty due to better understanding of process or better measurement of parameters. In addition, examine how new advances in technology can affect high impact parameters and processes. Determine how detailed conceptual models developed under basic and applied science in DOE programs or other programs (e.g NABIR program, Nuclear Regulatory Commission natural analog studies, Petroleum Industry studies) can be applied to DOE sites under remediation or being closed.

Expected Products/Results: Identification of parameters and processes with highest impact on uncertainty and risk.

Prerequisites: Understanding of risk and uncertainty, knowledge of detailed conceptual models from basic and applied science programs and other relevant programs.

Estimated Duration: 1 year

Task #4 Validate the conceptual model

Description: Use existing monitoring data to evaluate the performance of the conceptual models. Additional monitoring data may be required to monitor critical parameters and processes identified in the sensitivity studies.

Expected Products/Results: Comparison of monitoring data to predicted performance using current conceptual model

Prerequisites: Results from tasks #1, 2, and 3. Existing monitoring data collected to date and possibly additional monitoring of parameters and processes identified in sensitivity analyses.

Estimated Duration: 2 years

Task #5: Modify/upgrade current conceptual model

Description: Identify sites where current conceptual models do not predict the performance of the remediation system. Modify or upgrade these conceptual models based on results of the sensitivity analyses and the existing monitoring data. Modifications should also incorporate knowledge on conceptual models from research sites.

Expected Products/Results: Modified or upgraded conceptual model.

Prerequisites: Results from tasks #1, 2, 3, and 4.

Estimated Duration: 1.5 years

Task #6: Cost/Benefit Analysis

Description: Conduct cost/benefit analysis of modified or upgraded conceptual model relative to reduction of risk and uncertainty. This cost/benefit analysis will include complete life-cycle costs (incorporating closure and long-term stewardship).

Expected Products/Results: Cost/Benefit analysis for modified or upgraded conceptual models

Prerequisites: Cost/benefit data related to modified or upgraded conceptual models; predicted closure and long-term stewardship costs.

Estimated Duration: 6 months

Task #7: Produce Guidance Document

Description: Develop guidance document outlining how to modify or upgrade existing conceptual models based on monitoring data and results from research sites. Case studies should be described for different GHBCT sites and different exposure pathways. Direct design of long-term monitoring systems to allow adaptation to changes in conceptual models. The guidance document should also include regulatory input to long-term stewardship monitoring systems and outline regular review of such systems.

Expected Products/Results: Guidance document

Prerequisites: Regulatory input, regulatory acceptance, information for case studies.

Estimated Duration: 1 year

Technology/Technique Descriptions

None identified

TARGET 1.2

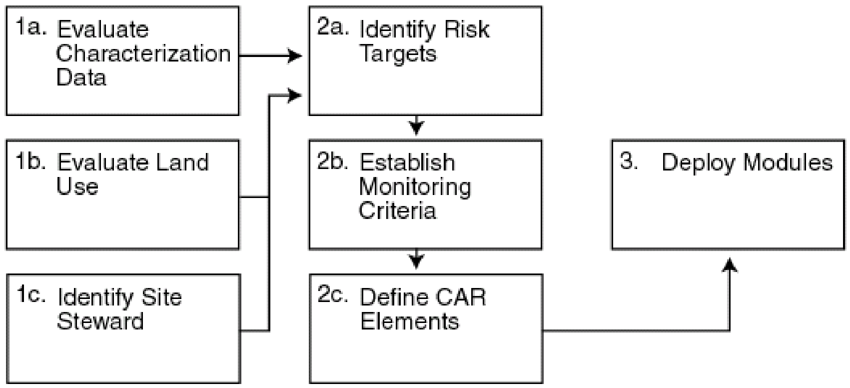
Develop characterization technologies and analytical tools that enable long-term forecasting of system performance.

Note: This target addresses capabilities to assist in the design of containment systems. It was originally integrated with other targets addressing both design and verification capabilities. While the individual targets were subsequently regrouped to improve the organization of the main report, the integrated pathway to achieve the set of design and verification capabilities was kept intact and may be found later in this appendix at Target 1.4b.

TARGET 1.3

Develop modeling tools for estimating the community at risk for an LTS site.

Capability Enhancement Pathway



Pathway Task Descriptions

Task #1: Define Characteristics

Description: Evaluate the characteristics of a range of sites to determine their relationship to definition of the community at risk (CAR). Note there are three subtasks:

a) Evaluate the characterization data and determine credible risks to adjoining community from the source term.

   Expected Products/Results: Establish credible and measurable targets to evaluate

b) Evaluate the land use controls established by the site (fragile vs firm) at the time of turn over.

   Expected Products/Results: The benefits of this assessment will determine how static the site boundaries will be.

c) Identify the site steward

   Expected Products/Results: The pedigree of the site steward will provide a prediction regarding the manner in which the site land will be used in the future.

Expected Products/Results: Gain essential technical information to base toxicological decisions and the degree of fragility and type of controls that will be established for site boundary and source term.

Estimated Duration: 1 year

Task #2: Develop Capability

Description: Develop the assessment methods to define the CAR. Note there are three subtasks:

a) From the list of credible targets, determine which could serve as a precursor of risk from the source term(s). Pathways described here are air, animal/insect vector and mechanical.

b) Based upon the results of Task #2a, establish criteria for sensor and monitors that meet the requirements for protection of the CAR.

c) Using, to a large part toxicological and epidemiological studies performed by DOD, EPA and the assistance of the National Institutes of Health, define the elements that need to define the boundaries of the CAR. Those elements are numerous but would include for example downwind vapor and particulate dispersion modeling, degradation rates of material in atmosphere, mobility and binding capabilities, generation of secondary agents, etc. The effects on the populations, and thus the boundaries, would vary depending on the expected lifestyle of the CAR. This would not be a map, wind rose, and protractor exercise.

Note: The above task 2a and 2b will be based upon the demographics and lifestyles of the population at the time of LTS. Adjustments may need to be made after a period of time for the following reasons:

- Targets are no longer remaining in the pathways as defined,
- Targets still remain but population has changed, i.e., age , lifestyle,
- CAR boundaries have moved closer or farther away from the source term
- Change in site end-state determination or designation.

Expected Products/Results:

Estimated Duration: 2 years

Task #3: Deploy Modules

Description: Establish a module that can be deployed for the 2008 closure sites.

Expected Products/Results: Once the targets and criteria are established, the modules can be developed that can serve any site in a tailored fashion to provide the guidance for protecting the community (if deemed necessary)

Estimated Duration: 2 months

Technology/Technique Descriptions

None identified

TARGET 1.4A

Provide performance data on experimental cover/cap systems and natural analogues, develop models for long-term natural processes that affect the performance of CC&C systems, and improve methodologies for prediction of failure modes and time to failure.

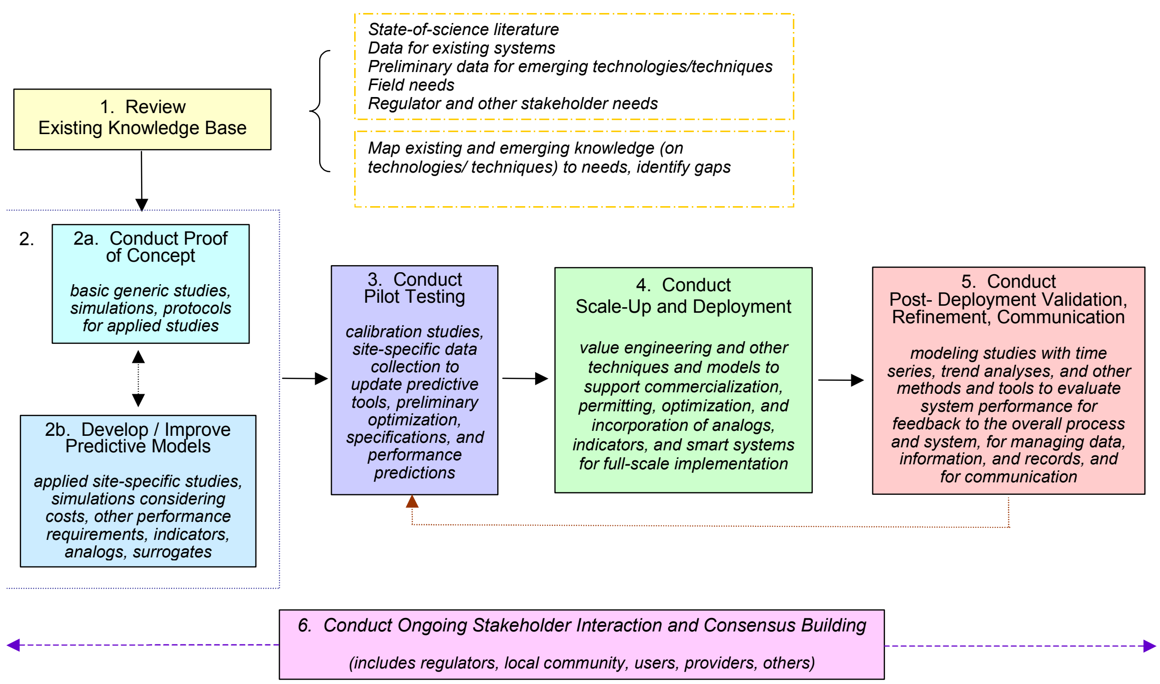
Note: This target addresses capabilities to assist in the design of containment systems. It was originally integrated with other targets addressing both design and verification capabilities. While the individual targets were subsequently regrouped to improve the organization of the main report, the integrated pathway to achieve the set of design and verification capabilities was kept intact and may be found later in this appendix at Target 1.4b.

TARGET 1.4B

Provide a suite of techniques and technologies (e.g., models, natural analogues, guidance, performance indicators, and failure criteria) to improve planning, decision making, design, monitoring, maintenance, and interpretation of monitoring data at and around CC&C systems.

Note: This target addresses capabilities to assist primarily in the verification of containment systems. It was originally integrated with other targets primarily addressing establishment of design requirements. While the individual targets were subsequently regrouped to improve the organization of the main report, the integrated pathway to achieve the set of design and verification capabilities was kept intact and is presented here. The related targets are Target 1.1 and Target 1.4a.

Capability Enhancement Pathway



Pathway Task Descriptions

This pathway is closely tied to those for *Capabilities and Targets 2.1, 2.2, 6.4* and, therefore, includes elements also reflected in those pathways, as well as certain costs.

Task #1. Review Existing Knowledge Base.

<u>*Description:*</u> This involves reviewing the existing scientific literature, site information, and other information sources, and interviewing site managers and their teams, research investigators, technology developers, other technique/technology users and providers, and stakeholders.

Prerequisites: None

Expected Products/Results: Status reports, lessons learned, and identification of gaps between existing resources and needs.

Duration: 6-12 months, with this effort being conducted in parallel for the eight technique/technologies identified on Form A.

Task #2a. Conduct Proof of Concept.

Description: This involves evaluating existing methods and tools for relevance to CC&C systems being developed or considered (baseline and alternate) and identifying opportunities for improvement.

Prerequisites: Products of Step 1.

Expected Products/Results: Reference and resource reports.

Duration: 6-12 months, with this effort being conducted in parallel for the eight technique/technologies identified on Form A.

Task #2b. Develop and Improve Predictive Models.

Description: This involves improving predictive methods and tools to increase their applicability to CC&C systems being developed or considered (baseline and alternate), including linking models to reflect coupled processes. New field data collection is not part of this task. Model development focuses on enhancing and integrating existing models rather than creating new ones.

Prerequisites: Products of Steps 1 and 2a.

Expected Products/Results: Handbooks and resource guides.

Duration: 6-12 months, with this effort being conducted in parallel for the eight technique/technologies identified on Form A.

Task #3. Conduct Pilot Testing.

Description: This involves collecting and incorporating site information into the evaluation and development of updated, somewhat validated methods and tools. Targeted data collection can reduce major uncertainties in the models that will in turn significantly reduce design conservatism and associated costs for CC&C systems. The schedule for this data collection is presented here because it represents activities in the field rather than paper or laboratory studies. (This main data collection effort is discussed under technique/technology #1 in Form A.)

Prerequisites: Products of Steps 1, 2a, and 2b.

Expected Products/Results: Initial site-specific models and other methods and tools.

Duration: 6-24 months, with this effort being conducted in parallel for the eight technique/technologies identified on Form A.

Task #4. Conduct Scale-Up and Deployment.

Description: This involves extending improved methods and tools to full-scale site application for CC&C systems being developed or considered (baseline and alternate). Limited additional data collection may also be involved. A portion of this step may overlap in time with Step 3, depending on the technique/technology type (e.g., for #9).

Prerequisites: Products of Steps 1, 2a, 2b, and 3.

Expected Products/Results: Improved site-specific models and other upgraded methods and tools that are more predictive and effective; site-specific design guides and protocols.

Duration: 12-24 months, with this effort being conducted in parallel for the eight technique/technologies identified on Form A.

Task #5. Conduct Post-Deployment Validation.

Description: This involves evaluating and further refining predictive models and other methods and tools in light of actual system performance.

Prerequisites: Products of Steps 1, 2a, 2b, 3, and 4.

Expected Products/Results: Lessons learned, refined site-specific models and other methods and tools, and improved protocols and procedures.

Duration: 12-24 months and longer (design life), with this effort being conducted in parallel for the eight technique/technologies identified on Form A.

Technical Approaches

Understanding the behavior of contaminated materials within the environmental settings unique to each stewardship site – which will continue to change over time – is crucial to identifying and implementing appropriate containment and control options and promoting the sustainability of these protective systems. This capability involves conceptualizing the integrated natural and engineered systems, enhancing predictive tools for evaluating CC&C system performance and understanding failure initiators, using natural analogs to predict environmental conditions and CC&C system responses over the long term, and incorporating this information into the ongoing design and refinement of these systems. The key emphasis is harmony with the natural environment, so CC&C systems work with and rely on natural processes rather than countering them.

An overview of the techniques/technologies within this capability is provided in Figure 1. This capability and target are closely linked with and support others in the CC&C area and interrelationships also exist among the individual techniques/technologies listed in this subsection. In addition, information from these capabilities flows to and from those of the other work groups.

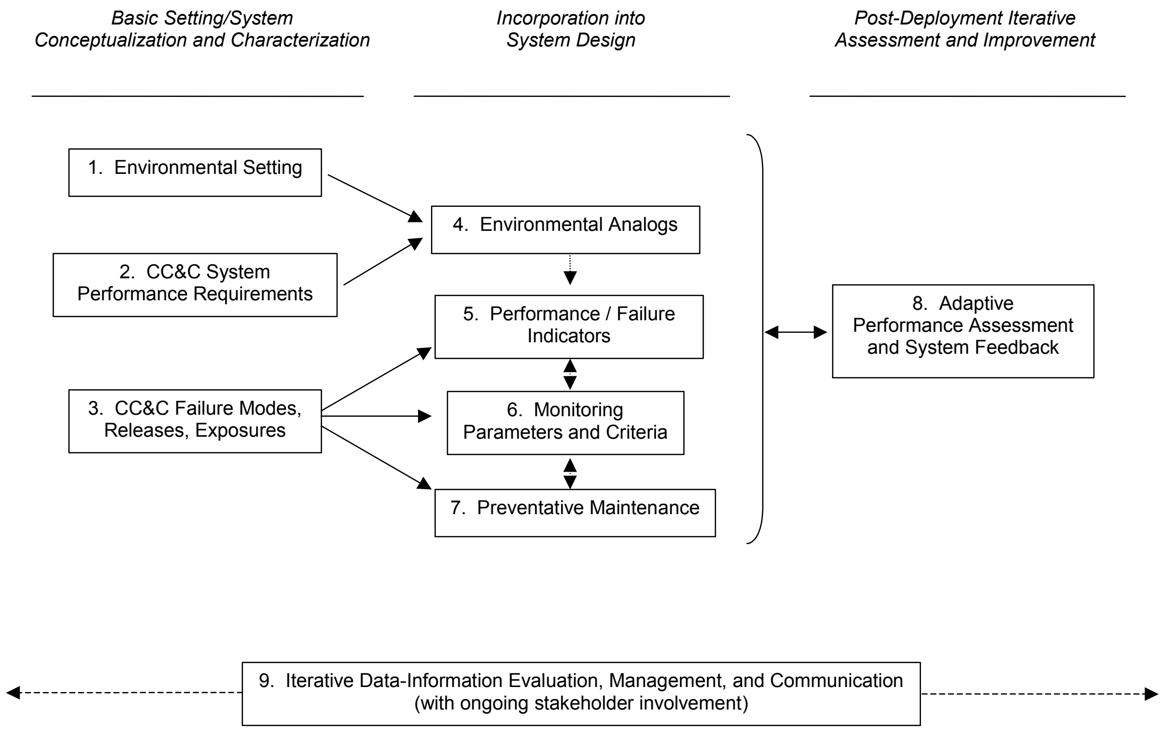


Figure 1.

Technique/technology # 1 (Environmental Setting)

Title: Characterize Current Environmental Settings and Predicted End States.

Description: Understanding current and projected environmental states at each stewardship site is needed to identify reasonable ranges for long-term changes that could lead to failure of CC&C systems over time. These conditions cover five major categories: (1) climate change; (2) ecological succession; (3) pedogenesis (including soil structure and horizon development, bioturbation, dessication, and freeze-thaw cracking); (4) landform processes (such as uplift resulting in topographic changes); and (5) land use, with primary emphasis on the next few generations. Also essential to this characterization is an understanding of how site contaminants behave in these settings. This characterization effort covers (1) transformation and attenuation (to more or less toxic forms, including through radioactive decay, biodegradation, hydrolysis, and photolysis); (2) mobility (including adsorption, fixation, and complexation); and (3) bioavailability, also considering uptake, transfer, and other partitioning factors.

Current Maturity Level: Basic environmental characterization and prediction methods are well developed and demonstrated. However, they have not yet been integrated across categories or sufficiently verified to provide the information needed for long-term CC&C systems. Similarly "immature" is the level of data available to address site-specific stewardship needs, including information on the behavior of contaminants and of systems that have been installed.

Range of Applicability: All stewardship sites.

Needed R&D:

A. For natural environmental settings:

1. Compile a *catalog* of current environmental states and ranges of predictions and associated uncertainties for future states across the five categories. For example, for climate change assemble information and projections for temperature, precipitation, seasonality, and extremes for each site region.

2. Develop *methods and tools* for combining these predictions to provide an integrated view, or preview, of future states for these site regions.

3. Develop *methods and tools* for history matching or hindcasting of integrated environmental conditions (e.g., using Monte Carlo and Bayesian approaches), and conduct this activity for each site region using data and proxies for past conditions to reduce the ranges of uncertainty in the compiled values.

4. Develop *guidance* for identifying and mapping analog sites and conditions and defining reasonable ranges for key characteristics within each of the five categories, and prepare an *atlas* of these maps and ranges for each site region.

B. For environmental contamination and control systems:

1. Compile existing site-specific data and identify key information still needed to reasonably address long-term stewardship questions, including through risk estimation and sensitivity analyses using current models and approaches. Prepare a *protocol* for collecting site-specific data to address these needs, incorporating both stakeholder involvement and the DQO process.

2. Collect new site data to fill the key gaps, to include consideration of the following (highlighted from Field presentations to the work groups in Orlando).

   a. Source characteristics

      - waste site boundaries and contents (including transuranic waste, fuel pools, asbestos, debris); fingerprinting to distinguish from background, other sources

      - subsurface facilities (including location and nature of piping)

      - surface facilities: physical hazards (structural stability) and biological and chemical hazards (ambient concentrations in indoor air, and moisture and temperature conditions conducive to biohazards, such as mold and mildew, hanta virus, and bubonic plague, and vectors such as mice, rats, and cockroaches)

   b. System characteristics, including barriers and treatment

      - intrusion deterrents and observations of changes in installed caps/covers
      - in-situ stabilization through better injection and dispersion of better agents
      - treatment to isolate metals and radionuclides, treatment of DNAPLs
      - preservation of cover integrity when monitors are emplaced and replaced; better predictions to reduce uncertainty for covers and barriers

- “minimum-safe” post-closure requirements

c. Release, transport, and fate characteristics, including hydrologic and other isolation

- leachate flow and quality; flow in fractured media
- decommissioning of groundwater wells and potential for preferential flow
- adsorption and other attenuation characteristics, including capacity of soil
- bioavailability of environmental contamination, effective biological half life

These characterization activities would be coordinated and conducted in parallel, such that the *methods, tools, and guidance* efforts described for the natural environmental setting (A.2-4 above) would also be conducted for conceptualization and characterization of “environmental contamination” and “control system” settings.

Links:

With Other CC&C Capabilities:

- Engineer Biogeochemical Environment (ground water environment): Provide up-front conceptualization and characterization of environmental setting and contaminant conditions and how they may change over time, with an emphasis on the subsurface, to support the feasibility and effectiveness evaluations of engineering options (such as reagent injection) for limiting contaminant toxicity and mobility.

With Other Work Groups:

- *Decision Making and Institutional Performance (DMIP)* and *Safety Systems and Institutional Controls (SSIC)*: Solicit and share information on the current state and reasonable range of projected land uses, with primary emphasis on near-term generations, for consistency and to limit the potential for pieces to “fall through cracks” (for the human element of the environment). Solicit input to the identification of key data gaps and data collection protocols, and provide newly collected data as scoping input.

- *Monitoring and Sensors (M&S):* Solicit information on larger-scale physical, biological, and chemical environmental monitoring and sensing to support hindcasting and characterization. Monitoring data and projections for land use (e.g., from remote sensing and predicted population patterns) are also included here if not already provided by DMIP and SSIC. Solicit input to the identification of key data gaps and data collection protocols, and provide newly collected data as scoping input.

Technique/technology # 2 (System Performance Requirements)

Title: Identify CC&C System Performance Requirements

Current Maturity Level: Basic methods for identifying generic performance requirements for engineered containment and control systems are well developed. However, they do not yet fully account for environmental settings and other local factors, nor are they being deployed for sustained effectiveness and efficiency over successive generations.

Range of Applicability: All stewardship sites.

Needed R&D:

1. Compile performance requirements for existing systems, extending beyond DOE to include commercial and municipal systems. Also compile information on the systems' abilities to achieve these requirements and active measures that have been taken to sustain performance, considering factors such as component reliability, time-to-correct or replace, ease-of-correction or replacement, and cost. Include key elements that affect performance, considering both those that sustain it and those that weaken it. Provide this information in a *"performance status" resource report.*

2. For sites that have not yet implemented CC&C systems: conceptualize and summarize contamination-setting-system configurations for both baseline and alternate systems; improve *methods and tools* for predicting system control capabilities (e.g., for controlling infiltration, leaching, drainage flux; gas release; slope instability, subsidence; erosion, soil loss; and biotic and human intrusion in arid, semi-arid, and humid settings); improve *methods and tools* for identifying system features critical to performance and reasonable ranges of performance. Provide this modeling and other predictive information in a *"conceptual performance requirements" resource report.*

3. Develop a *method* and *protocol* for soliciting and incorporating user, provider, and stakeholder needs and issues into system requirements to identify reasonable performance envelopes.

4. Develop a *guide* for defining and refining performance requirements for specific CC&C systems that considers system response to environmental change.

Links:

With Other CC&C Capabilities: Provide improved front-end conceptualization and understanding of the surface and subsurface environment, the contamination, and the engineered system, including how the risk-driving components of each can change over time and what responses are needed. Support site-specific integration of these elements to result in effective and efficient CC&C systems. Links with all five CC&C capabilities, with the first three being primary:

- Design, build, and operate alternate containment systems (cover barriers)
- Design, build, and operate alternate containment systems (subsurface barriers)
- Identify and implement improved responses to change (via routine and preventive maintenance that nurtures system performance) and failure (via corrective repair, retrofit, and replacement)
- Engineer Biogeochemical Environment (ground water environment)
- Engineer Biogeochemical Environment (source)

With Other Work Groups:

- *DMIP:* Provide conceptualization of integrated system (source, setting, engineering measures) to support related stakeholder discussions. Solicit results of stakeholder involvement and incorporate those needs and issues into CC&C performance requirements guide and protocol.

- *SSIC:* Provide conceptualization of integrated system as scoping input to the evaluation of safety systems and access controls, including information for the target contaminant list based on site-specific risk factors (considering source, setting, and expected capabilities of engineered controls). Solicit results of that evaluation to incorporate into the performance requirements guide and protocol. As above, solicit input to and results of stakeholder involvement.

- *M&S:* Solicit results from performance monitoring of existing systems. Provide conceptualized configurations, key elements, designed control capabilities, and reasonable performance envelopes as scoping input to the development of new monitors and sensors. Solicit capabilities that can support enhanced system performance monitoring to incorporate in the guide and protocol.

Technique/technology # 3 (Failure Modes, Releases, Exposures)

Title: Identify System Failure Modes, Release Processes, and Exposure Pathways

Current Maturity Level: Basic methods for identifying generic failure modes and release processes are needed. So are general, idealized transport and fate models and a standard exposure assessment methodology. These will need to be integrated across the whole system (waste source, CC&C configuration, and environmental setting), and verified for site-specific conditions. Also, current models still represent fairly simple cases and are not yet well enough developed to accurately represent real, heterogeneous environments (such as flow in fractured media / other preferential flows, site-specific attenuation characteristics, or susceptibility to and recovery from exposure effects.)

Range of Applicability: All stewardship sites.

Needed R&D:

1. Compile a *resource handbook* of information and models for the following.

   a. Failure events and conditions, with probabilities, consequences, and uncertainties

      - natural events by region, such as earthquakes, fires, floods, and damaging winds
      - engineered system (whole and components) failure modes and initiating conditions

   b. Release process and transport and fate models, to focus on risk drivers

   c. Exposure pathways and associated risks

2. Prepare a *guide* for enhancing and linking models of coupled processes, incorporating probabilistic and Bayesian approaches. Include in the guide *checklists* for maintaining overall fidelity across models, as well as illustrative *examples*.

   a. Failure event probability / consequence models
   b. System performance / risk models
   c. Ecosystem/water balance models
   d. Release, contaminant transport and fate, hydrobiogeochemical models
   e. Exposure / effect models (e.g., to incorporate susceptibility knowledge emerging from genomics, proteomics, cumulative risk studies)

3. Run linked models and conduct sensitivity analyses, and use results to refine *methods and tools* for identifying further site-specific data needed to reduce the range of key uncertainties, and thus conservatism in system designs. Prepare a *protocol* for collecting these additional data, incorporating stakeholder involvement and the DQO process.

4. Collect the needed site data and incorporate them into improved *coupled models*, making them relevant and more capable of reasonable predictions. This involves further conceptualization and numerical modeling, model integration, and verification/validation. Provide these models and results in tiered *guides* to represent the overall system and its components, capturing failure modes, release processes, and potential exposure issues. (For example, an umbrella report or primer would cover broadly common elements and could be complemented by regional or site-specific guides that cover additional location-specific features.)

5. Develop *methods and guidance* for scoring the significance of system conditions that reflect different stages (from precursor to full) of different modes of failure, and for linking these to monitoring and countermeasure protocols. These should incorporate stakeholder involvement and be geared to site-specific application considering expected and alternate source-setting-system configurations.

Links:

With Other CC&C Capabilities:

- Provide better system conceptualization and coupled models (improved by site-specific data) to guide analysis and selection of system design, operation, and maintenance.

With Other Work Groups:

- *M&S:* Solicit input on system failures and conditions, the scoring method, and the approach for linking to monitoring protocols. Provide model results and key site/system data as scoping input for monitor and sensor development.

- *SSIC:* Solicit input on and results of land use control and projected receptor analyses (access/ exposure restrictions), and on stakeholder involvement processes and the results of those involvements. Solicit input on failure modes for institutional controls, including probabilities, consequences, and uncertainties. Solicit input on the scoring system, link to countermeasures (and monitoring if not addressed by M&S). Provide model results and key site/system data as scoping input for safety systems and institutional controls.

- *DMIP:* Solicit input on failure modes for institutional systems (as described above for institutional controls) and on the scoring system and link to countermeasures. Solicit input on stakeholder involvement processes and the results of those involvements. Provide model results and key site/system data as scoping input for decision making and institutional performance.

Technique/technology # 4 (Environmental Analogs)

Title: Identify and Integrate Analogs of Long-Term Environmental Change into System Design

If location-appropriate analogs of natural processes were fully incorporated into CC&C system design, it would greatly strengthen system resilience to environmental changes, which we know will occur.

Not only will these alternate systems be much more effective, they will be much cheaper than current systems which require extensive active management to offset the impacts of natural processes.

<u>*Current Maturity Level:*</u> Methods for identifying natural analogs are reasonably well developed for a range of system features. However, methods for integrating these analogs into CC&C systems for sustained effectiveness over the long term are not yet well developed and are not yet widely deployed.

<u>*Range of Applicability:*</u> All stewardship sites.

<u>*Needed R&D:*</u>

1. Develop *methods and tools* for identifying environmental analogs to support the long-term viability of CC&C systems, and compile an *analog catalog* – a set of environmental analogs by resource and location/region with associated ranges and uncertainties (e.g., for geologic/ slope stability, vegetation and sustained water balance, and biointrusion resistance).

2. Develop *methods and protocols* for designing and implementing accelerated ("compressed-time") tests that simulate future environmental conditions, to evaluate resilience of baseline and alternate CC&C systems.

3. Synthesize results of bench-scale and pilot tests of simulated system performance in a *case study summary* to facilitate identification of natural design features that accommodate long-term change for specific systems. Using these results, develop *methods and tools* for identifying key system elements for various source-system-setting configurations and the optimum analogs for those elements, with expected ranges and uncertainties.

4. Develop *methods* for integrating analogs of long-term environmental change into CC&C systems. Prepare *protocols* for design teams to implement on a site-specific basis that include opportunities for stakeholder input (e.g., an umbrella primer and tiered guides).

<u>*Links:*</u>

With Other CC&C Capabilities:

- 2.2 (primary)
- 6.4, 2.1 (secondary)

With Other Work Groups:

- *M&S:* Solicit past monitoring and sensing data for long-term change and expectations of data generated by ongoing or planned studies. Solicit input to and provide the design guide, and also case study information, as scoping input for monitor and sensor development.

- *SSIC:* Solicit input regarding changes in land use controls (access/exposure restrictions). Solicit input on protocols for obtaining and incorporating stakeholder input, and solicit results of stakeholder involvement activities. Provide case study and other information as scoping input for safety systems and institutional controls.

- *DMIP:* Solicit input on obtaining and incorporating stakeholder input and solicit results as above. Provide case study and other information as scoping input to decision making and institutional performance.

Technique/technology # 5 (Performance / Failure Indicator)

Title: Identify and Integrate Performance and Failure Indicators into CC&C Systems.

Indicators are needed to assure that individual components (e.g., barrier, collection, and treatment components) and whole systems are operating within expected performance envelopes. Indicators are also needed to identify when the system is failing, including early warnings or precursors. Chemical, geophysical, and biological indicators must be integrated during the design and construction phases of new systems or the maintenance and upgrade phases of current systems to achieve effective, efficient CC&C for the long term.

Current Maturity Level: The methods and tools for identifying short-term performance and failure indicators are reasonably well developed (e.g., for solid and municipal waste landfills and mill tailings cells). However, they are not well developed for complex systems and have not yet been deployed to reliably indicate performance and failure over the long term.

Range of Applicability: All stewardship sites.

Needed R&D:

1. Compile definitions and indicators of performance and failure used for existing systems, as well as those planned for systems being designed and implemented. Provide these in a general *"indicators" reference report*.

2. Conceptualize and develop integrated *methods and tools* for understanding system behavior over a reasonable range of environmental setting and system conditions in order to define key failure points, using updated and enhanced models with probabilistic and Bayesian approaches. Prepare a *reference handbook* of these modeling approaches to cover all major source-system-setting configurations; also in this handbook identify important performance and failure indicators for baseline and alternate CC&C systems as indicated by model simulations.

3. Collect site and system data to improve these *models*, extending them from generalized laboratory conditions to field conditions, identifying key vulnerabilities and reducing uncertainty ranges (and related design conservatism). Develop *methods and tools* to evaluate indicators and surrogates of performance and failure in the context of natural environmental changes, to include comparative analyses for reference sites.

4. Develop improved *methods, tools, and protocols* for identifying, prioritizing and selecting core performance and failure indicators and surrogates on a site-specific basis, to include input from users, providers, and stakeholders.

5. Develop *methods, tools, and protocols* for incorporating selected indicators or surrogates of performance and failure into CC&C systems – as part of the design-construction phase for those in development, and as part of the upgrade phase for those already in place.

Links:

With Other CC&C Capabilities:

- 2.2, 6.4 (primary)
- 2.1 (secondary)

With Other Work Groups:

- *M&S:* Solicit input on performance and failure indicators for CC&C systems per current monitoring information, and provide the reference report and handbook as scoping input for monitor and sensor development. Solicit input on methods for evaluating, prioritizing, and selecting core indicators and for incorporating them into systems, and provide these methods as scoping input to M&S development.

- *SSIC:* Solicit input on the performance and failure of safety systems and institutional controls, and on obtaining and incorporating stakeholder input to methods and protocols. Provide the reference report and handbook, as well as methods and protocols, as scoping input for SSIC.

- *DMIP:* Solicit input on the performance and failure of institutional systems and stewardship decisions, and on obtaining and incorporating stakeholder input to methods and protocols. Provide the reference report and handbook, as well as methods and protocols, as scoping input for DMIP.

Technique/technology # 6 (Monitoring Parameters and Criteria)

Title: Identify Monitoring Parameters and Criteria, and Integrate into CC&C Systems

Current Maturity Level: Methods for identifying monitoring parameters for basic CC&C systems are reasonably well developed, but they have not yet been tailored for nor widely implemented in complex systems designed for long-term protection. Similarly, methods for defining general criteria for these parameters are fairly well developed, but site-specific criteria using the DQO process have not been effectively deployed for complex systems.

Range of Applicability: All stewardship sites.

Needed R&D:

1. From existing systems, compile key parameters, ranges, uncertainties, and acceptable deviations. Conduct trend analyses that take into account environmental characteristics and other factors. Present this information in a *monitoring reference handbook.*

2. Develop improved *methods and tools* for identifying, prioritizing, optimizing, and selecting risk-driving parameters and surrogates to be monitored, such as cap moisture, infiltration, and outflow rate from reactive barriers. Address integrated area monitoring and remote sensing, incorporate stakeholder inputs, and consider the following:

    a. Integrity and protectiveness of CC&C systems – surface and subsurface

    b. Hazards – chemical, physical, & biological (e.g., invasive species, infectious agents)

c. Indicators of system stress, precursors of loss of effectiveness (e.g., vegetation changes)

3. Develop improved methods and tools for identifying, prioritizing, optimizing, and selecting quantitative criteria for these parameters, including reasonable ranges and acceptable deviations. Also develop improved methods and tools for threshold levels and triggers of different types or levels of response (e.g., blue = watch list, yellow = warning, red = action). Include provider, user, and other stakeholder inputs.

4. Develop improved methods and tools for identifying, prioritizing, optimizing, and selecting monitoring locations and frequencies, including for remote sensing (e.g., for contaminated materials ranging from buried transuranic waste to buildings and debris, and for environmental characteristics ranging from land use to vegetation and wildlife changes). Include provider, user, and other stakeholder inputs.

5. Develop streamlined methods and tools for acquiring, aggregating, integrating, evaluating, presenting, communicating, and archiving data, and for optimizing its reliability and utility (see T/T #9). Include provider, user, and stakeholder input.

6. Develop methods and protocols for integrating selected monitors and sensors into CC&C systems – during the design and construction phases for new systems and during the maintenance and upgrade phases for existing systems – and for refining or upgrading these monitors and sensors as dictated by system needs and the availability of more efficient and effective technologies. Include provider, user, and other stakeholder inputs.

Links:

With Other CC&C Capabilities:

- 2.2, 6.4 (primary)
- 2.1 (secondary)

With Other Work Groups:

- *M&S:* Solicit input from past monitoring activities for the reference handbook, parameters and surrogates, criteria, locations and frequencies, data and information management and communication, and refinement of M&Ss, and provide materials developed as input to M&S activities.

- *SSIC:* Solicit input from past monitoring activities, as described above but specific to safety systems and institutional controls. Include means for obtaining and incorporating stakeholder inputs.

- *DMIP:* Solicit input from past monitoring activities, as described above but specific to decision making and institutional performance. Include means for obtaining and incorporating stakeholder inputs.

Technique/technology # 7 (Preventive Maintenance)

Title: Identify Preventive Maintenance Requirements and Integrate into CC&C Systems

Current Maturity Level: Methods for identifying preventive maintenance requirements are somewhat well developed. However, they have not yet been widely deployed to support efficient CC&C systems.

Range of Applicability: All stewardship sites.

Needed R&D:

1. Compile information on preventive maintenance requirements from existing operation and maintenance (O&M) plans and case histories, and prepare a *"status and lessons learned" resource report*.

2. Develop *methods and tools* for identifying, prioritizing, optimizing, and selecting measures for baseline and alternate CC&C systems under various source-setting-system configurations, to incorporate into system design. Incorporate user, provider, and other stakeholder input.

3. Develop *methods and tools* for system diagnosis and defining appropriate correction or repair measures for existing systems (both current ones and those to be implemented) over time, e.g., to (a) unclog drains, pipes, trenches: (b) remove scaling and de-foul surfaces; (c) re-seal transmission lines, implement self-healing barriers; (d) stabilize structures against physical deterioration; (e) seal/ activate automated self-treatment against biohazards; and (f) define mobile contingency treatment units. Incorporate user, provider, and other stakeholder input.

Links:

With Other CC&C Capabilities:

- 2.2, 6.4 (primary)
- 2.1 (secondary)

With Other Work Groups:

- *M&S:* Solicit input from past monitoring for the case histories and methods and tools, and provide materials developed as scoping input to M&S development, evaluation, and refinement.

- *SSIC:* Solicit input regarding safety systems and institutional controls for the case histories and methods and tools, and provide materials developed as scoping input to SSIC.

- *DMIP:* Solicit input regarding decisions and institutional performance for the case histories and methods and tools, and provide materials developed as scoping input to DMIP.

Technique/Technology # 8 (Adaptive Performance Assessment and Feedback)

Title: Integrate Field Tests, Analogs, and Models for Performance Assessment and Feedback

The objective of CC&C systems at stewardship sites is to sustain protection over the long term. Thus, iterative performance assessments are needed to integrate ongoing field tests and analogs of system performance with predictive models, and a process is needed to ensure that resulting information is fed back to the system to guide appropriate modifications.

Current Maturity Level: Evaluation methods for field testing are well developed, as are general predictive models for performance assessment. However, observations of installed systems are not being widely recorded and shared in an organized, consistent manner; natural analogs are not yet well represented in system performance assessments; methods for adaptive updating are not well developed; and results are not widely deployed for feedback to improved CC&C systems.

Range of Applicability: All stewardship sites.

Needed R&D:

1. Compile results of current field tests for specific source-system-setting configurations, including pilot-scale and partially implemented systems, and compile performance predictions for systems in the design or planning stages. Provide this information in a *"performance assessment" resource report*.

2. Develop a *protocol* for the consistent recording of observed changes in installed systems, addressing all CC&C system components – including caps and other covers (e.g., considering crack formation, animal burrowing, and vegetation establishment), vertical and horizontal subsurface barriers, leachate collection systems, permeable reactive barriers, grouts, and water treatment media. Develop a *guide* for measuring the effects of these changes on system properties significant to performance, and develop a *process and tool* for sharing this information broadly (see T/T #9).

3. Develop *methods and tools* for iterative performance assessment, with an emphasis on the analysis of potential failures and related impacts as system and setting conditions change over time, using probabilistic and Bayesian approaches. Provide this modeling information in a *"performance assessment" reference handbook*.

4. Develop *methods and tools* for adaptively updating field test designs and refining analogs over time.

5. Develop *methods and tools* for integrating field test, analog, and performance assessment information to provide feedback for guiding system improvements (to prevent failures or offset impacts).

6. Develop an *approach and protocol* for triggering system upgrades that reflects combined input from the technical team and stakeholders, and provide these in tiered *guides* such as general primers complemented by field guides for site-specific implementation.

Links:

With All Other CC&C Capabilities:

- 2.1, 2.2, and 6.4

With Other Work Groups:

- *M&S*: Solicit input on performance data from current system monitoring, and provide the resource report as scoping input for monitor and sensor development. Solicit input on methods for adaptive assessments, updated protocols with system feedback, and determining indicator upgrades, and provide these methods and approaches as scoping input to M&S development.

- *SSIC*: Solicit input on adaptive performance assessment for safety systems and institutional controls, and solicit results of related stakeholder involvement activities. Provide the resource report and methods for adaptive assessments, including feedback and refinement, as scoping input for SSIC.

- *DMIP*: Solicit input on adaptive performance assessment for decision making and institutional performance, and solicit results of related stakeholder involvement activities. Provide the resource report and methods for adaptive assessments, including feedback and refinement, as scoping input for DMIP.

Technique/Technology # 9 (Iterative Information Evaluation and Communication)

Title: Conduct Ongoing Data-Information Evaluation, Management, and Communication

Current Maturity Level: Methods for evaluating data and information, maintaining records, and refining systems are fairly well developed, as are standard communication methods. However, these have not yet been well integrated or deployed for long-term systems.

Range of Applicability: All stewardship sites.

Needed R&D:

1. Compile and synthesize the following in a *"stewardship information" status report* (e.g., to be regularly updated over >10-20 years to capture lessons learned and best practices for iterative refinement of processes and means being used at DOE stewardship sites).

   Note: See * below for the types of data that could be included in stewardship reporting.

   a. Stewardship data being collected for CC&C systems, including from Grand Junction and other programs, and expectations for data from systems being put in place and those in the design and planning modes. Include: for what purposes these data are collected; data quality and traceability; platform, form and format; backup methods and processes (e.g., microfilm or duplicate files in regional and national storage); and methods or procedures used to define requirements for what data are collected and how they are evaluated (including how false positives, false negatives, and outliers are identified and managed), and use of meta data.

   b. Methods and tools being implemented and planned for managing data, information, and records transfer – addressing such issues as indexing, file compatibility, and feasibility and necessity of synchronization (many legacy databases are in outdated software, some may not warrant the effort it would take to include) notably for sites transitioning from active cleanup to stewardship. Include information from pilot projects for Nevada (database integration) and Grand Junction (information portal, geographic information systems [GIS], records management), as well as projects from Rocky and Ohio (records management).

   c. Methods and tools being implemented and planned for communicating stewardship knowledge, including accessibility (e.g., LTS website and other electronic means, administrative records or reading rooms in site areas, national storage file) and active dissemination over space, time, and audience accounting for different levels of operational need (e.g., site, local authorities, community, general public, other sites).

   d. Current and planned roles and responsibilities for collecting, integrating, interpreting, communicating, transferring, and maintaining data, information, and records, e.g., a *steward's plan*.

   e. What data that consider long-term implications are being incorporated into current environmental management decisions, and how this is being done (e.g., life-cycle analyses and cost tradeoffs and related decision-making tools).

2. Using this information as a foundation, conduct an updated *needs assessment* to identify parties with a need for or interest in stewardship knowledge, and solicit inputs – ranging from core information needs and approaches for defining these, to roles and responsibilities and general long-term plans for data, information, and records management including organizational and infrastructure measures and data integration.

3. Using results of 1-2, develop improved *methods and tools* for the following, and provide this information in a *"data identification, integration,& interpretation" resource handbook*

   a. Defining core requirements; developing a flexible, comprehensive taxonomy (with general categories and specific data elements to accommodate both national and site-specific needs); integrating data acquisition (including from automated systems, laboratories, and observations recorded on paper); harmonizing measurement methods, network topologies, and programs; assuring and scoring data quality (e.g., through "fit-to-use" criteria developed from cost-benefit models, artificial intelligence methods, and statistical tools with graphical interfaces); evaluating time-dependencies (e.g., from diurnal to seasonal changes and beyond); developing flexible data structures (e.g., electronic formats) and processes for transformation (to a uniform basis), transfer (e.g., through teleinformatic networks), and storage (e.g., in a source database with a centralized warehouse and data marts); defining a distributed system architecture; archiving for both direct data access and automated, regular updating of interpretive plots, graphs, and thematic maps with intelligent interface (e.g., using a meta-base with standard vocabularies using expert systems and artificial neural networks)

   b. Aggregating and interpreting raw data across system components, environmental resource types, and monitored parameters over space and time, including through integrated electronic data processing, GIS and adaptive visualization techniques, and use of meta-information or catalog systems with advanced query tools

   c. Preparing interpretive summaries focused on the bottom line and tailored for different audiences (see 1c), to include background context and trend analyses, and considering server security (e.g., with firewalls)

   d. Incorporating this information into CC&C system design, operation, and maintenance, such as through improved decision support system (DSS) shells (for which artificial intelligence shells are often the base technology) and simulation models to predict outcomes of proposed decisions, together with access to materialized views of warehoused data (mindful of stored data security as needed, e.g., with Java Servlets).

4. Compile information management (IM) and information and communication technology (ICT) *methods and tools*, evaluate their evolution to date and projected advances (e.g., third-

generation mobile/wireless communication with base stations and routers; flat screens versus cathode ray tubes), evaluate ICT equipment and application requirements and costs, and develop *plans* for adapting to IM-ICT changes over time (as these will certainly occur). Provide this information in an *"IM-ICT" reference report*.

5. Develop methods, processes, and tools for information communication, considering shared, layered, and open architectures and integrated infrastructures (with exchange formats and protocols, metadata harmonization, front-end data servers and application servers as generic model adapters for metadata systems), communication infrastructure (with registries for data definition and XML schemes, and for on-line information on servers; and a call server for managing communication between clients and the distributed system), simplified user interfaces (considering internet/intranet techniques); and tools for supporting priority data flows.

6. Develop optimization *methods and tools* to define umbrella and site-specific plans for managing data, information, knowledge, and records, with an emphasis on streamlining (to identify "min-safe" needs and non-resource-intensive processes to limit space, time, and cost requirements) and communicating priority information.

7. Develop improved *methods and tools* for soliciting feedback on this shared knowledge to identify system needs (including institutional components) and trigger responses, including approaches for linking with decision systems, such as multi-criteria spatial decision support tools.

8. Evaluate and develop improved *methods, tools, and procedures* for communicating failure-triggering events and conditions and potential consequences and their significance. For immediate threat situations, the communication component would include rapid notification of multiple parties by multiple means (redundant backups could include audio, visual, and active contact via smart-tags and automated activation of wireless technology). For non-emergency situations, this could lower-level broadcast, involvement, backup, and response triggers (e.g., similar to tornado watch and warning).

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* For example, site information would be expected to include the following.

a. Legal-compliance: regulatory standards and Orders; permits, licenses, authorizations, and certifications; withdrawals, leases, easements, rights-of-way, access and use restrictions; mining and water rights; tribal agreements; required effectiveness reviews, other agreement milestones and schedules

b. Environmental setting: initial and post-closure, with trend analyses and background information

   - resources (characterization records): hydrology (surface, ground water); topography, soil, geology (geochemistry, geotechnical, geomorphology, seismicity); biota, succession; air, meteorology, climate; natural catastrophic events; historic, archaeological, cultural properties; land use, demographics, infrastructure, economics

- contamination (monitoring records): nature and extent of residual contamination across environmental media, post-cleanup verification surveys

c. CC&C systems:

- siting and design basis, specifications and performance envelopes, drawings and as-builts, delineated system area with buffer zone, O&M plans, costs
- contents: volumes, types / matrixes, concentrations, emplacement records
- related infrastructure, transportation, safety records

d. Communication systems-plans: including roles and responsibilities, means

- routine: information type & level, accessibility, dissemination, maintenance
- emergency: notification and response, contingencies

Links:

With Other CC&C Capabilities:

- 2.1, 2.2, and 6.4

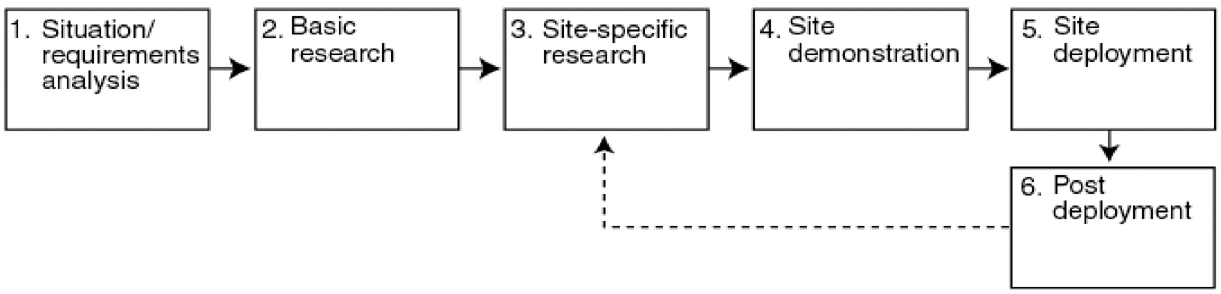
With Other Work Groups:

- *M&S:* As indicated above, solicit input to methods and tools and provide related information as scoping input to M&S development, evaluation, and refinement.
- *SSIC:* As indicated above, solicit input to methods and tools related to data, information, knowledge, and communication regarding safety systems and institutional performance, and provide summaries, methods, tools, and plans as scoping input to SSIC. Included is soliciting input on means for obtaining and incorporating stakeholder and other institutional inputs and lessons learned sharing information.
- *DMIP:* As indicated above, solicit input to methods and tools related to data, information, knowledge, and communication for decisions safety systems and institutional performance, and provide summaries, methods, tools, and plans as input to DMIP. Included is soliciting input on means for obtaining and incorporating stakeholder and other institutional inputs, lessons learned sharing information, and input on institutional frameworks and processes for IM and decision making.

TARGET 2.1A

Deploy alternative technologies that detoxify or immobilize risk-driving contaminants at the source.

Capability Enhancement Pathway



Pathway Task Descriptions

The traditional waterfall model is the natural way of managing the development of something innovative and complex. In using the waterfall model the project proceeds according to clearly defined phases; a preceding phase must be completed before the next starts; phase completion is judged by the outcome of the phase matching the requirements defined by the previous phase. The phases of the traditional model are:

1. Concept
2. Feasibility analysis
3. User Definition of System Requirements
4. Developer Definition of System Requirements
5. High-Level Design
6. Detailed Design
7. Prototype development
8. Integration and Test
9. System Test
10. Acceptance Test
11. Operations
12. Maintenance.

To achieve target 2.1a, the LTS CC&C Workgroup consolidated the traditional waterfall model into the tasks shown in the figure and discussed below.

Task #1: Situation/Requirements Analysis (Pre-lab/field research).

<u>*Description:*</u> Review and status the current knowledge and needs in the following areas and map existing and emerging knowledge (items a-c) to needs (items d-e) and identify gaps.

(a) State-of-science literature review
(b) Existing system / performance data
(c) Emerging technology / preliminary data
(d) Field needs (user)
(e) Regulator and stakeholder needs (step 1 of ongoing consensus building)

Expected Products/Results: Reports and papers describing the current knowledge, needs and the mapping results.

Estimated Duration: 1 – 6 months

Task #2: Basic Research.

Description: Perform theoretical and laboratory based proof of concept research. Following are example areas where this work may need to be performed:

(a) Generic treatability studies (e.g., effectiveness and reasonable ranges for reagent and delivery mode)

(b) Predictive models and tools (e.g., simulation of fate and transport, protocols for applied studies)

(c) Regulator and stakeholder input.

Expected Products/Results:

Expected Duration: 6 – 24 months

Task #3: Site-specific Research.

Description: Perform theoretical and laboratory based proof-of-application research. Following are example areas where this work may need to be performed:

(a) Site-specific treatability studies (considering contaminants, matrix, environmental setting for site-specific system requirements)

(b) Predictive models and tools (e.g., site-specific fate and transport simulation over time; considering expected change, cost and other performance requirements, indicators, surrogates, and analogs)

(c) Regulator and stakeholder input – interaction.

Expected Products/Results:

Expected Duration: 6 – 12 months

Task #4: Site Demonstration

Description: Perform pilot testing. Following are example areas where this work may need to be performed:

(a) Field tests (scale-up from lab/bench-scale trials, calibration studies)

(b) Predictive models and tools (performance standards, optimization studies with predictions of performance over time, preliminary specifications)

(c) Regulator and stakeholder input – interaction.

Expected Products/Results:

Expected Duration: 6 – 12 months

Task #5: Site Deployment.

Description: Perform scale-up and deployment activities. Following are example areas where this work may need to be performed:

(a) Engineering analysis, cost analysis, commercialization and vender selection / full-scale implementation

(b) Predictive models and tools (to optimize final system design, incorporating smart monitoring and maintenance that promote elements of the natural system and considering full life-cycle costs)

(c) Regulatory approval (e.g., license, permit), regulator and stakeholder input – interface

Expected Products/Results:

Expected Duration: 6 months

Task #6: Post-Deployment.

Description: Perform validation through iterative system refinement / replacement. . Following are example areas where this work may need to be performed:

(a) Evaluation of system performance / monitoring data
(b) Predictive models and tools (time series / trend analyses)
(c) Regulator and stakeholder input – interaction
(d) Info management and overall process system feedback loop (of items a-c).

Expected Products/Results:

Expected Duration: 3 months

Technology/Technique Descriptions

Soil Vapor Extraction

Description: Soil Vapor Extraction (SVE) consists of an array of extraction wells, screened within the zone of contamination, that are equipped with an extraction pump capable of pulling enough air to maintain a vacuum within the zone of influence. Soil gases are pulled off and directed into a process train, which treats the gases prior to emission to the atmosphere. The system can be run intermittently (pulsed) once the extracted mass removal rate has leveled off. Pulsed operation can increase the effectiveness of the process. SVE addresses only volatile and some semi-volatile contaminants, and may enhance biodegradation of low-volatility organic compounds. A geosynthetic material may be required over the surface during this process to prevent short circuiting (break-through at the ground surface). Soil that has a high percentage of fines and a high degree of saturation will require higher vacuums and/or will hinder operation of the process. Application in soils with highly variable permeabilities may exhibit uneven delivery of gas flow resulting in less effectiveness in the lower permeability areas (FRTR 2001).

Current Maturity Level: Being applied

Range of Applicability: Effective at reducing volatile and semi-volatile organic contaminants in the subsurface. Preferentially removes materials from high permeability zones in the subsurface, but can be pulse-operated to allow diffusion to increase removal. Not effective for non-volatile organics, most inorganics, and radionuclides.

Needed R&D: None identified.

Sources/References:

FRTR, 2001, Federal Remediation Technologies Roundtable, *Remediation Technologies Screening Matrix and Reference Guide Version 3.0.* (Information also available at http://www.frtr.gov, updated 12-13-2001.)

Low Pressure Grouting

Description: Permeation grouting involves injecting low viscosity grout formulations into the subsurface under gravity feed or low pump pressures. The grout permeates porous media and has been shown to encapsulate waste debris. Previously proven grouts include colloidal silica, polysiloxane, ultra-fine cement-based grouts, and polyacrylamide.

Current Maturity Level: Being applied

Range of Applicability: Very low permeabilities can be achieved in homogeneous media. At heterogeneous sites, it is difficult to ensure consistent applications across the subsurface. This process depends on the permeability, microstratigraphy, and porosity of the formation to be grouted (Hayward Baker 2001) and is most effective in media with homogeneous characteristics.

Needed R&D: None identified

Sources/References:

Hayward-Baker, 2001, Permeation Grouting, ISSMFE-TC-17, available at: http://www.tc17.poly.edu/Permeation_Grouting.htm.

Injection (High Pressure) Grouting

Description: Jet grouting involves use of a positive displacement pump to deliver grout to a drill rig, which injects the material into the waste zone through the drill string at 6000 pounds per square inch (psi) (400 bar). A thrust block—a massive concrete template with spaced holes and a void space beneath— can be used to ensure the grid spacing is maintained and workers are protected from returning contaminated grouts. The grout may be injected as the drill casing is inserted or as it is removed from full depth. The process requires site characterization and material testing to determine a suitable grouting agent. Many different grouts are available, including chemical grouts, which are injected as solutions rather than suspensions of particles in a fluid medium which defines cementitious grouts (USACE 1995). For long-term stabilization, a dense, low-porosity grout can be used to chemically and physically bind the waste.

Current Maturity Level: Being applied

Range of Applicability: Injection grouting has been demonstrated to significantly reduce hydraulic permeability. In addition, certain grout types chemically alter infiltrating water, reducing the solubility potential of contaminants. Grouting also minimizes landfill subsidence, which improves the performance of low-permeability cover systems. As with other in situ techniques, verification that all areas have been uniformly treated is difficult. This necessitates long- term monitoring of leachate to ensure protectiveness.

Jet grouting can be used effectively in soil types ranging from gravel to heavy clays (Mutch et al. 1997). Jet grouting has been repeatedly demonstrated on soil and waste sites.

Needed R&D: Techniques to control the potential spread of contamination resulting from contaminated grout returns have not yet been demonstrated.

Sources/References:

Mutch, R. D., R. E. Ash, and R. J. Caputi, 1997, "Contain Contaminated Groundwater," *Chemical Engineering*, Vol. 104, No 5, pp. 114-119.

USACE, 1995, *Engineering and Design – Chemical Grouting*, EM 1110-1-3500, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, January 31, 1995. (Also available at: http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-1-3500/toc.htm.)

Enhanced Soil Mixing

Description: In Situ Enhanced Soil Mixing is a process that has been used to remediate soils contaminated with volatile organic compounds, especially those of fine-grained nature. A single-blade auger or a combination of augers ranging from 1 to 4 m (3 to 12 ft) in diameter is used to mix the soils. This process option is combined with a number of other process options to either remove or stabilize contaminants of concern in place. The four main options for soil mixing include combination with vapor extraction and ambient air injection; vapor extraction and hot air injection, hydrogen peroxide injection; and grout injection for solidification/stabilization.

Current Maturity Level: Being applied

Range of Applicability: Effective at treating contaminants of concern depending on the combination of processes used. With soil vapor extraction, the mixing can be used to enhance stripping action. In situ peroxidation oxidizes volatile organic compounds (VOCs), while mixing cement grout under pressure can solidify the subsurface mass.

Needed R&D: Auger systems have to be tested under site-specific conditions to determine their performance under the given geologic conditions.

Soil Flushing

Description: Water is applied to the soil (sometimes with an additive to enhance contaminant solubility). Contaminants are dissolved into the pore water, extracted through wells, and then sent through a treatment train. Co-solvent flushing is an adaptation of soil flushing that uses a solvent mixture (e.g., water plus a miscible organic solvent such as alcohol). The target contaminant groups include inorganics (including radioactive contaminants), though VOCs, semi-volatile organic compounds (SVOCs), fuels, and pesticides may also be treated.

Current Maturity Level: Being applied

Range of Applicability: The process is more applicable to coarse-grained soil conditions (FRTR 2001). The process involves flushing water through the contaminated zone so potential contamination spreading and nuclear criticality hazards could limit its acceptability.

Needed R&D: None identified

Sources/References:

FRTR, 2001, Federal Remediation Technologies Roundtable, *Remediation Technologies Screening Matrix and Reference Guide Version 3.0.* (Information also available at http://www.frtr.gov, updated 12-13-2001.)

Chemical Leaching

Description: Contaminated wastes are leached with an appropriate leaching solution and the elutriate is collected in a series of shallow well points or subsurface drains. This process option is more commonly performed as an ex situ technology, eliminating concerns about toxicity of residual leachant.

Current Maturity Level: Under development

Range of Applicability: The process is only effective in areas of relatively high permeability and on contaminants that have relatively high solubility. Also, the process is not effective for waste zones that are in contact with fractured rock vadose zones due to difficulties associated with collection of the elutriate.

Needed R&D: None identified

Hydrolysis

Description: Hydrolysis is used to break down certain chemicals by reacting them with water.

Current Maturity Level: Under development

Range of Applicability: Many pesticides, including aliphatic halides, amides, carbonates, and others, are susceptible to partial decomposition by hydrolysis (McBride 1994). Additionally, the process has been used for degradation of explosives and has been investigated for immobilization of radioactive elements (Nash 2000).

Needed R&D: Little data about the effectiveness of the process during in situ remediation efforts has been collected. Additionally, contaminant-specific catalysis mechanisms and reaction rate information is generally incomplete.

Sources/References:

McBride, M.B, 1994, *Environmental Chemistry of Soils*, Oxford University Press, New York.

Nash, K.L., 2000, Thermally Unstable Complexants/Phosphate Mineralization of Actinides, Argonne National Laboratory, Argonne, IL. (Also available at: http://www.ornl.gov/divisions/ctd/ESP/96tasks/thermal.htm, posted April 14, 2000.)

Reduction/Oxidation State Manipulation

Description: Reduction/oxidation reactions chemically convert hazardous contaminants (primarily metals) to less toxic and/or less mobile or inert compounds (CPEO 1998). Materials that can be injected into the subsurface to provide in situ oxidation include iron filings (zero-valent iron), and potassium permanganate grout. In situ reduction/oxidation -manipulation creates a treatment zone in the subsurface for remediation of reduction/oxidation -sensitive contaminants in groundwater, including chromate, uranium, technetium, some chlorinated solvents, and some explosive compounds. Aquifer sediments can be chemically manipulated (reduced) so that they become the reactive media. Gaseous reduction is also being tested on chromate contaminated sites. Numerous other mechanisms are available for either reducing or oxidizing contaminants.

In situ hydrous pyrolysis/oxidation oxidizes dense nonaqueous phase liquid (DNAPLs) through the injection of steam and oxygen in contaminated soils (WPI 1998). This process is described under Steam Injection.

Current Maturity Level: Under development

Range of Applicability: Process may have limited applicability at sites that contain a wide range of contaminants. The reason for this limitation is that a given reduction/oxidation reaction will limit the mobility of some contaminants while enhancing the mobility of others.

Needed R&D: Site-specific and contaminant-specific treatability studies are usually needed before implementation of reduction/oxidation manipulation.

Sources/References:

CPEO, 1998, *Soil Flushing*, project of the San Francisco Urban Institute at San Francisco State University, Center for Public Environmental Oversight, posted in the Technology Tree webpage at http://www.cpeo.org/techtree/ttdescript/soilflus.htm, created August 24, 1998.

WPI, 1998, *In Situ Redox Manipulation*, available at http://www.lwpi.org/Initiatives/init/winter98/awards.htm.

In Situ Thermal Desorption

Description: ISTD uses electrical resistance heating elements through rods in a thermal well system. Applications to date have been up to 4.3 m (14-ft) deep (USACE 2000). The waste and contaminated soil are heated to temperatures between 315 and 538^{o}C (600 and 1,000 F) to vaporize and destroy most organics. An aboveground vapor vacuum collection and treatment system destroys or absorbs the remaining organics and vents carbon dioxide and water. Achieving temperatures up to 427^{o}C (800ºF) may take 3 months or longer.

Current Maturity Level: Under development

Range of Applicability: ISTD can effectively remove volatile and semi-volatile COCs as well as potentially destroy combustible organics depending on the temperatures and heating times maintained. While generally applied to organic contaminants, the process reportedly "has the potential to chemically stabilize plutonium and other radionuclides and metals and reduce their mobility" (Jorgensen et al. 1999).

Needed R&D: None identified

Sources/References:

Jorgensen, D. K., D. F. Nickelson, R. A. Hyde, R. K. Farnsworth, J. J. Jessmore, 1999*, Evaluating In Situ Treatment Technologies for Buried Waste* Remediation *at the INEEL*, INEEL/CON-98-00879, Pre-print for publication in Waste Management 1999, February-March 1999.

USACE, 2000, *Hydrologic Evaluation of Landfill Performance, Version 3.07*, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Steam Injection

Description: Steam injection (a.k.a., dynamic underground stripping) targets organics, especially SVOCs and fuels, but can also be used to recover some inorganics. Steam is injected into the subsurface through injection wells. Vaporized contaminants, air, and water are recovered with vacuum extraction wells and treated.

Current Maturity Level: Under development

Range of Applicability: The process has been widely used in the petroleum industry to enhance oil field production and its basic aspects are well understood. It has been used for remediation at depths between 1.5 and 36.5 m (5 and 120 ft). steam injection has also been used with bioremediation by injecting oxygen after the steam process to enhance microbial metabolism (CPEO 1998; DOE/EM 1997).

The process requires injected steam to contact the surfaces of contaminated soil particles and is therefore dependent on air conductivity of the subsurface. The process has limited applicability in fine-grained materials or in waste zones with irregular permeabilities.

Needed R&D: The potential for criticality inducement should be investigated when process will be used in source zones that contain fissionable materials.

Sources/References:

CPEO, 1998, *Soil Flushing*, project of the San Francisco Urban Institute at San Francisco State University, Center for Public Environmental Oversight, posted in the Technology Tree webpage at http://www.cpeo.org/techtree/ttdescript/soilflus.htm, created August 24, 1998.

DOE/EM, 1997, *In Situ Vitrification Fact Sheet*, Department of Energy and the Environmental Management Program available at http://www.bechteljacobs.com/emef/newfacts/facts/insituvit.html.

Thermally Enhanced Vapor Extraction

Description: Thermally Enhanced Vapor Extraction combines thermal desorption principles with soil vapor extraction. The subsurface is heated with an array of electrodes. Vapors are extracted via extraction wells, screened within the zone of contamination, and equipped with extraction pumps capable maintaining a vacuum within the zone of influence. Soil gases are recovered and directed through a process train which treats the gases prior to emission to the atmosphere as in traditional SVE (CPEO 1998).

Current Maturity Level: Under development

Range of Applicability: Effective at reducing volatile and semi-volatile organic contaminants in the subsurface. Preferentially removes materials from high permeability zones in the subsurface, but can be pulse-operated to allow diffusion to increase removal. The process is generally not effective for non-volatile organics, most inorganics, and radionuclides.

Needed R&D: None identified

Sources/References:

CPEO, 1998, Soil Flushing, project of the San Francisco Urban Institute at San Francisco State University, Center for Public Environmental Oversight, posted in the Technology Tree webpage at http://www.cpeo.org/techtree/ttdescript/soilflus.htm, created August 24, 1998.

Radio Frequency Heating

Description: Radio Frequency Heating uses radio frequency energy applied through exciter electrodes to heat the subsurface and volatilize certain organic contaminants, especially VOCs and SVOCs. Closely spaced electrodes are required, as each heating zone has an approximate 1 m (3 ft) radius of influence. Operating temperatures, selected for the target contaminants, are generally on the order of 150ºC (302ºF), but can reach up to 1330ºC (2426ºF) at exciter electrodes (EPA 1995). Soil gases are recovered with vacuum extraction and directed through a process train that treats the gases.

Current Maturity Level: Being applied

Range of Applicability: The use of RFH process is limited to the vadose zone, and is not effective near or below the water table.

Needed R&D: None identified

Sources/References:

EPA, 1995, IITRI Radio Frequency Heating Technology – Innovative Technology Evaluation Report, EPA/540/R-94/527, Superfund Innovative Technology Evaluation (SITE), Environmental Protection Agency, Washington D.C., June 1995.

In Situ Vitrification

Description: In Situ Virtification uses electrical heat to melt soil and waste into a mass of fused glass similar to obsidian. Electrodes inserted into the ground in a square array transmit current to the soil until it melts, volatilizing VOCs and SVOC and immobilizing other COCs in the process. As the electrodes sink through the molten material, the melt zone advances downward. Off-gases from the process are collected and treated. Planar ISV provides preferential pathways for the escape of vapors between the two planar melts until they fuse together. A 3 m (10 ft) thick cover of unconsolidated materials is maintained over the melt zone in the application of planar ISV. This zone protects equipment and personnel at the surface from exposure to heat and molten soil expulsions. Melts up to 13.7 m (45 ft) in diameter have been produced. Melts can be overlapped to treat a large site.

Current Maturity Level: Under development

Range of Applicability: The attainable depth of In Situ Vitrification has been increasing as the technology improves. Currently, the deepest ISV melt has penetrated to 8 m (26 ft) below the ground surface (MSE Technology Applications 1999).

Needed R&D: More information about the differentiation of metals within the melt zone is needed. This differentiation has the potential for limiting the long term effectiveness of ISV melts at some sites.

Sources/References:

MSE Technology Applications, 1999, Final Report – Cold Demonstration of Nontraditional In Situ Vitrification at the Los Alamos National Laboratory, ECCP-11, prepared for the Department of Energy, Los Alamos National Laboratory, Los Alamos, New Mexico, November 1999.

Electro Kinetic Remediation

Description: Electrokinetic remediation removes metal and radionuclide contaminants from the soil by applying a low-level direct current to the contaminated zone with electrodes placed in the ground. ER uses electromigration of ionic species and electro-osmosis. The process works in low-permeability soils, imposing a high degree of control of flow direction as ions move along electric field lines determined by electrode placement. Contaminants are extracted from the circulating electrolytes inside the electrodes.

Current Maturity Level: Under development

Range of Applicability: Effectiveness depends on interfering chemicals and adequate current density (USACE 2000). May be effective in fine-grained soils where most extraction methods are least efficient (EPA 1999). Field scale test results for US Army were disappointing (USACE 2000).

Needed R&D: None identified

Sources/References:

EPA, 1999, *SITE Technology Profile Demonstration Program,* EPA/540/R-99/500a, Superfund Innovative Technology Evaluation (SITE), Environmental Protection Agency, Washington D.C., February 1999.

USACE, 2000, Hydrologic Evaluation of Landfill Performance, Version 3.07, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

In Situ Anaerobic Bioremediation

Description: In situ anaerobic biological degradation is generally used for particular contaminants that are not readily degraded by aerobic treatment, such as highly substituted aliphatics and highly chlorinated aromatics, including tetrachloroethene, PCBs, and hexachlorobenzene. A typical anaerobic system injects an electron donor substrate into the subsurface (EPA 1999). Airflow into the treatment zone may need to be controlled so that anoxic conditions are maintained.

Current Maturity Level: Under development

Range of Applicability: May not be effective in low-permeability conditions or in containerized waste. Not well suited to fine-grained soils (CPEO 1998). Process also may have limited utility at large sites due to the need to maintain anoxic condition

Needed R&D: None identified

Sources/References:

EPA, 1999, SITE Technology Profile Demonstration Program, EPA/540/R-99/500a, Superfund Innovative Technology Evaluation (SITE), Environmental Protection Agency, Washington D.C., February 1999.

Aerobic Bioremediation

Description: In situ aerobic biological treatment results in the transformation or mineralization of organic contaminants caused by the activities of naturally occurring or specifically engineered microorganisms. Depending on the microbial population and dominant processes, these activities can either break down organic contaminants or mobilize inorganic contaminants for removal. Microbes are affected by temperature, moisture, nutrients, and oxygen, which can be optimized to maximize treatment. Also, specific microbial organisms can be injected to target a particular contaminant. A typical system injects oxygen, or other nutrients, to enhance the growth of microbial populations. Aerobic degradation involves higher metabolic rates, and is generally preferred over anaerobic systems. Process options may be combined to address particular contaminants that would benefit from first anaerobic, then aerobic, degradation (EPA 1999).

Current Maturity Level: Under development

Range of Applicability: Some chemicals may be degraded to more toxic products (e.g., trichlorethene to vinyl chloride) (CPEO 1998). May not be effective in low-permeability conditions or in containerized waste. May be difficult to control in fine-grained soils.

Needed R&D: None identified

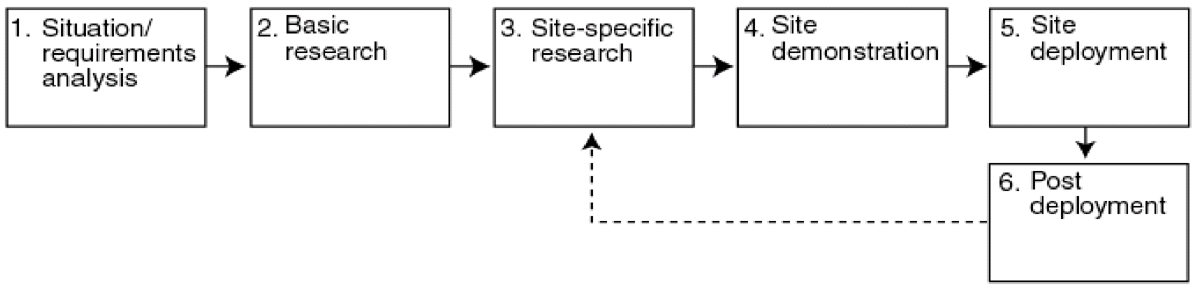
Sources/References:

CPEO, 1998, *Soil Flushing*, project of the San Francisco Urban Institute at San Francisco State University, Center for Public Environmental Oversight, posted in the Technology Tree webpage at http://www.cpeo.org/techtree/ttdescript/soilflus.htm.

TARGET 2.1B

Deploy alternative technologies that reduce the volume of groundwater that would otherwise have been pumped and/or treated.

Capability Enhancement Pathway



Pathway Task Descriptions

To achieve target 2.1a, the LTS CC&C Workgroup consolidated the traditional waterfall model (see Pathway for Target 2.1a) into the tasks shown in the figure and discussed below.

Task #1: Situation/Requirements Analysis (Pre-lab/field research).

<u>*Description:*</u> Review and status the current knowledge and needs in the following areas and map existing and emerging knowledge (items a-c) to needs (items d-e) and identify gaps.

(a) State-of-science literature review
(b) Existing system / performance data
(c) Emerging technology / preliminary data
(d) Field needs (user)
(e) Regulator and stakeholder needs (step 1 of ongoing consensus building)

<u>*Expected Products/Results:*</u> Reports and papers describing the current knowledge, needs and the mapping results.

<u>*Estimated Duration:*</u> 1 – 6 months

Task #2: Basic Research.

<u>*Description:*</u> Perform theoretical and laboratory based proof of concept research. Following are example areas where this work may need to be performed:

(a) Generic treatability studies (e.g., effectiveness and reasonable ranges for reagent and delivery mode)

(b) Predictive models and tools (e.g., simulation of fate and transport, protocols for applied studies)

(c) Regulator and stakeholder input.

Expected Products/Results:

Expected Duration: 6 – 24 months

Task #3: Site-specific Research.

Description: Perform theoretical and laboratory based proof-of-application research. Following are example areas where this work may need to be performed:

(a) Site-specific treatability studies (considering contaminants, matrix, environmental setting … for site-specific system requirements)

(b) Predictive models and tools (e.g., site-specific fate and transport simulation over time; considering expected change, cost and other performance requirements, indicators, surrogates, and analogs)

(c) Regulator and stakeholder input – interaction.

Expected Products/Results:

Expected Duration: 6 – 12 months

Task #4: Site Demonstration

Description: Perform pilot testing. Following are example areas where this work may need to be performed:

(a) Field tests (scale-up from lab/bench-scale trials, calibration studies)
(b) Predictive models and tools (performance standards, optimization studies with predictions of performance over time, preliminary specifications)
(c) Regulator and stakeholder input – interaction.

Expected Products/Results:

Expected Duration: 6 – 12 months

Task #5: Site Deployment.

Description: Perform scale-up and deployment activities. Following are example areas where this work may need to be performed:

(a) Engineering analysis, cost analysis, commercialization and vender selection / full-scale implementation

(b) Predictive models and tools (to optimize final system design, incorporating smart monitoring and maintenance that promote elements of the natural system and considering full life-cycle costs)

(c) Regulatory approval (e.g., license, permit), regulator and stakeholder input – interface

Expected Products/Results:

Expected Duration: 6 months

Task #6: Post-Deployment.

Description: Perform validation through iterative system refinement / replacement. . Following are example areas where this work may need to be performed:

(a) Evaluation of system performance / monitoring data
(b) Predictive models and tools (time series / trend analyses)
(c) Regulator and stakeholder input – interaction
(d) Info management and overall process system feedback loop (of items a-c).

Expected Products/Results:

Expected Duration: 3 months

Technology/Technique Descriptions

There are 176 groundwater plumes across the DOE complex. Baseline cleanup/closure plans and life-cycle cost estimates for many of these plumes assume that alternatives to pump and treat will be deployed. However, because needed science and technology does not yet exist to implement alternative technologies for many of these plumes, long-term pump-and-treat still must be assumed to be the default technology for these plumes. Deployment of alternatives to pump and treat would allow DOE to realize substantial cost savings. Also, at several DOE sites it is expected or planned that contaminated water will be collected (for example, in french drains) over the long term for ex situ treatment. Engineering of the thermobiogeochemical environment could reduce the volume of water requiring treatment at these sites.

Phytoremediation and Phytotechnology

Description: Use phytoremediation to destroy, detoxify, or immobilize contaminants and phytotechnology to manipulate plume hydraulics

Current Maturity Level: Under development – Ranges from demonstrated/accepted technology (for a limited range of applications) to investigational technology (for other applications).

Range of Applicability: All applications are limited to locations where contaminants or contaminated water are present in the shallow subsurface (within depths of plant roots). Phytoremediation involves the use of plants and plant physiological processes (primarily in the rhizosphere) to destroy, detoxify, or immobilize contaminants. Phytoremediation has been successfully demonstrated, and thus is potentially applicable, primarily for nitrates (including explosives, in soil or in plumes) and other nutrient-rich plumes and secondarily for organic plumes. Phytotechnology to manipulate plume hydraulics is potentially applicable to plumes in shallow alluvial aquifers (on stream terraces and floodplains) in subhumid-to-arid locations (where plant water utilization can substantially affect water flux).

Needed R&D:

- Conduct site-specific treatability studies, including plant screening and selection for specific applications, water balance studies, bench and pilot scale measurements of uptake/transformation rates, model and predict site-specific performance, and evaluate whether results and predictions are acceptable

- Review post-deployment monitoring results and assess the performance of predictive models
- Develop design and application improvements based on post-deployment data and sensitivity studies with assessed predictive models
- Improve understanding of rhizosphere transformation processes and contaminant fate (needed to build confidence in long-term effectiveness and safety of phytoremediation)

Sources/References:

http://www.rtdf.org/public/phyto/default.htm - Phytoremediation of Organics Action Team of Remediation Technologies Development Forum

http://www.wes.army.mil/el/phyto/ - Phytoremediation Research at U.S. Army Corps of Engineers Waterways Experiment Station Environmental Laboratory

http://clu_in.org/products/phytotce.htm - Phytoremediation of TCE in Groundwater using *Populus*, prepared for the U.S. EPA Technology Innovation Office by Jonathan Chappell. February 1998.

http://www.gwrtac.org/html/topics/phytorem.htm - Technology Evaluation Report: Phytoremediation, Ground-Water Remediation Technologies Analysis Center, October 1997

Enhanced bioremediation.

Description: Bioremediation involves the use of microbial processes to destroy, detoxify, or immobilize contaminants. This occurs naturally to some extent, but enhanced bioremediation involves manipulation of natural systems to facilitate or accelerate the natural processes.

Current Maturity Level: Under development – Demonstrated/accepted technology for organics and nutrients. Investigational technology for metals and radionuclides.

Range of Applicability: Potentially applicable to almost all plumes. However, plume depth and geohydrologic complexity place practical limits on application for all contaminant types, not all metals and radionuclides are treatable with bioremediation, and complex mixtures of contaminants may not be treatable.

Needed R&D:

- Perform basic and site-specific research to demonstrate applications for metals and radionuclides.
- Perform basic and site-specific research to demonstrate applications for deep plumes in complex geohydrologic settings.
- Develop improved capabilities to deliver agents to stimulate bioremediation (such microorganisms, nutrients, air, carbon sources, and electron donors and acceptors), more efficiently, at greater depths, and in more complex geologic settings.
- Treatability studies needed to apply effectively and optimize application at specific sites.
- Perform R&D needed to build confidence in bioremediation:

– Develop improved prediction and understanding of system performance in order to achieve regulatory and stakeholder acceptance of these technologies.

– Develop an improved understanding of biological transformations for DOE metal and radionuclide contaminants and of the long-term stability of the apparently stable/immobile forms produced by bioremediation.

– Develop an improved understanding of the nature and environmental fate of breakdown products for chlorinated organics,.

– For all applications, develop improved understanding of long-term behavior and performance of bioremediation systems, including biofouling and other effects on hydraulic and geochemical characteristics of flow media.

Sources/References:

http://www.itrcweb.org/isb_6.pdf - Technical and Regulatory Requirements for Enhanced

In Situ Bioremediation of Chlorinated Solvents in Groundwater, December 1998, Interstate Technology and Regulatory Cooperation Workgroup In Situ Bioremediation Subgroup

U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Use of Bioremediation at Superfund Sites. EPA-542-R-01-019, September 2001.

http://www.lbl.gov/NABIR/generalinfo/primer/primer.html – Bioremediation of Metals and Radionuclides - What it is and how it works. Natural and Accelerated Bioremediation Research program (NABIR) of the Office of Biological and Environmental Research of the DOE Office of Science.

http://www.lbl.gov/NABIR/researchprogram/researchtopics/index.html - Natural and Accelerated Bioremediation Research program research topics

Note: NABIR projects a 7-to-10-year time frame to field demonstration of strategies to accelerate intrinsic processes for immobilization of metals and radionuclides. See http://www.lbl.gov/NABIR/researchprogram/researchtopics/biotransformation.html

http://www.lbl.gov/NABIR/generalinfo/workshop_reports/Final_Workshop.pdf – Workshop Report: "Combined Chemical and Microbiological Approaches to Remediating Metal and Radionuclide Contaminants" 1999.

Related techniques/technologies:

Target 2.1a, Tech. 15: In Situ Anaerobic Bioremediation
Target 2.1a, Tech 16: In Situ Aerobic Bioremediation

Subsurface introduction of chemical reactants, including passive reactive barriers.

Description: Chemical reactants can be injected directly into plumes or incorporated in passive barrier designs to capture, decompose, or otherwise neutralize the effects contaminants.

Current Maturity Level: Under development – Being field-demonstrated and/or used commercially in the form of passive-reactive barriers for treatment of plumes containing nutrients, organics, and chromate. Other applications potentially applicable to DOE, including (1) injection of chemical reactants directly into plumes and (2) use of passive reactive barriers for metals and radionuclides, are in laboratory investigation or early stages of field investigation. The feasibility of this technology and the choice of chemical reactants are highly contaminant-specific. Many applications involve introduction of oxidizing or reducing agents to change the chemical speciation, and thus the solubility, of inorganic contaminants or to induce the decomposition of organic contaminants. Other applications and potential applications involve (1) the introduction of neutralizing agents to control contaminant solubility by changing the pH of the plume and (2) the introduction or emplacement of reactive media (such as zeolite or apatite) to capture contaminants through ion exchange or similar reactions.

Range of Applicability: Potentially applicable to many plumes. Technical constraints currently impede use for deep plumes and for plumes in low-permeability and complex/heterogeneous geologic media.

Needed R&D:

- Investigate/develop passive-reactive barrier materials for use with metals, radionuclides, and plumes that include mixtures of contaminants.
- Investigate/develop the potential to introduce chemical reactants in the form of gases and colloids to overcome constraints associated with various complex geologic settings and with implementing remediation in the presence of buried utilities and other facility infrastructure.
- Demonstrate capabilities for in situ placement of chemical reactants (in all settings).
- Develop and demonstrate techniques for deep emplacement (and verification of deep emplacement) of passive reactive barriers.
- Develop improved understanding of phenomena affecting passive-reactive barrier performance over the short and long term, including reaction kinetics, role of microbial interactions in contaminant degradation, and fundamental understanding of processes that lead to degradation or clogging of barrier media, including biofouling, corrosion, and precipitation of reaction products.
- Demonstrate passive reactive barrier technology using metallic iron to treat organic solvent plumes at shallow to moderate depth.
- Site-specific treatability studies.
- Develop improved methods for monitoring system effectiveness and maintaining system performance.

Sources/References:

http://www.itrcweb.org/ISCO_1.pdf - Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater, Interstate Technology and Regulatory Cooperation Work Group In Situ Chemical Oxidation Work Team, June 2001.

http://www.rtdf.org/public/permbarr/default.htm - Permeable Reactive Barriers Action Team of the Remediation Technologies Development Forum

http://www.rtdf.org/public/permbarr/minutes/061201.htm - Summary of the Remediation Technologies Development Forum Permeable Reactive Barriers Action Team Meeting, June 12, 2001. (Summaries and discussions of ongoing research and findings, including investigations of emplacement techniques and barrier performance, investigations of new barrier materials, a permeable reactive barrier incorporating zeolite to remove strontium, and use of ultrasound to reduce clogging in an in-place metallic iron barrier.)

http://207.86.51.66/download/rtdf/prb/reactbar.pdf - Permeable Reactive Barrier Technologies for Contaminant Remediation, EPA/600/R-98/125. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response and Office of Research and Development.

http://www.lbl.gov/NABIR/generalinfo/workshop_reports/Final_Workshop.pdf – Workshop Report: "Combined Chemical and Microbiological Approaches to Remediating Metal and Radionuclide Contaminants" 1999.

http://www.powellassociates.com/sciserv/Perm.barrier.main.html - "Permeable Reactive Barriers Notebook"

LTS database references (Long Term Stewardship Technology Analysis of the Office of Science and Technology Profile, September 2001):

Surface Altered Zeolites as a Permeable Barrier (page 159), Verification of Subsurface Barriers/Moisture Detection (page 178), Subsurface Barrier Emplacement (page 191), In Situ Redox Manipulation (page 192), Permeable Reactive Treatment (PeRT) Wall for Rads and Metals (page 207), Fracture Permeable Reactive Barrier (page 224), Reactive Barrier Performance: DNAPL (page 252)

Related techniques/technologies:

Target 2.1a, Tech. 8: Reduction/Oxidation State Manipulation

Target 2.1b, Tech 2: Enhanced bioremediation (*related because microbial processes can contribute to, interfere with, and/or be adversely affected by measures to engineer chemical reactions in the environment*)

Engineered Wetlands.

Description: Engineered wetlands can destroy, detoxify, or immobilize contaminants in water through a combination of processes including physical sedimentation (of suspended material or contaminants precipitated by other chemical reactions occurring in the wetland system), microbial processes, plant physiological processes, chemical precipitation, and adsorption/ion exchange in wetland soils.

Current Maturity Level: Under development – This technology is demonstrated/accepted technology for treating stormwater runoff, acidic mining wastes (typically containing heavy metals whose solubility is controlled by pH), some organics, and small flows of sanitary wastewater. Investigational in other applications. The feasibility and implementation of this technology are highly contaminant- and site-specific.

Range of Applicability: Shallow drains and other locations where contaminated groundwater discharges to the surface. *Also potentially applicable (as a retrofit) under capability 5.1, as a longer-lived* *water treatment technology to reduce required maintenance interventions in installed contaminant control systems that include water collection and treatment.*

Needed R&D:

- Determine potential applicability to radionuclides and other DOE contaminants, both generically and for specific waste sources and sites (site-specific treatability studies needed before implementation).

- Develop efficient methods for monitoring system performance.

- Develop improved methods for maintaining system performance (*capability 5.1*)

Sources/References:

http://www.clu_in.org/download/remed/constructed_wetlands.pdf - Constructed Wetlands: Passive Systems for Wastewater Treatment, Technology Status Report prepared for the U.S. EPA Technology Innovation Office, August 2001

Related techniques/technologies:

Target 2.1b, Tech 1: Phytoremediation
Target 2.1b, Tech 2: Enhanced bioremediation

Air Sparging and Soil Vapor Extraction

Description: Air sparging and vapor extraction are used to remove volatile contaminants from soil.

Current Maturity Level: Being applied – Demonstrated / accepted for organics.

Range of Applicability: Organic plumes in relatively permeable settings.

Needed R&D:

- Determine risk and regulatory acceptability of air releases using simulation of fate and transport and discussions with regulatory personnel to define needs

- Conduct treatability studies using post-deployment monitoring at sites where technologies are deployed. Use these results to improve designs and simulations.

Sources/References:

http://www.gwrtac.org/html/topics/soilvapor.htm - Soil Vapor Extraction / Dual Phase Extraction, Ground_Water Remediation Technologies Analysis Center, October, 1996

http://www.gwrtac.org/html/topics/airsparg.htm - Air Sparging _ Technology Overview, Ground_Water Remediation Technologies Analysis Center, October, 1996

Related techniques/technologies:

Target 2.1a, Tech # 1, Soil Vapor Extraction – This technology is applicable to control of organic contaminants at the source or in the environment.

Dynamic Stripping for DNAPLs

Description:

Current Maturity Level: Being applied – Demonstrated at field scale.

Range of Applicability: Broad range of DNAPL contaminants, limited to vadose zone.

Needed R&D: "Confidence building" activities to move from state-of-art to state-of-practice.

Sources/References:

> http://www.rtdf.org/public/flushing/default.htm – In Situ Flushing Action Team of the Remediation Technologies Development Forum

Related techniques/technologies:

> Target 2.1a, Tech. 10: Steam Injection

TARGET 2.2A

Deploy cover systems that mimic natural processes and accommodate environmental change.

Capability Enhancement Pathway

1. Review cover design & performance criteria →
2. Investigate climate change →
3. Reconnaissance for analog sites →
4. Characterize analog sites →
5. Incorporate results in cover design process

Pathway Task Descriptions

An example application of Target 2.2A was developed for the Rocky Flats Environmental Technology Site (RFETS) to illustrate the type of support that could be provided to the EM Thrust Areas sites. The following technology pathway outlines specific steps for incorporating methods *to mimic natural processes and accommodate environmental change* in the process of designing ET caps for RFETS.

Task #1: Review Existing RFETS Cover Design and Performance Criteria

Description: Perform the following activities:

a. Review RFETS data on contaminant sources, mobility, and release and exposure scenarios. Determine whether cover performance criteria have been established (e.g. maximum allowable drainage flux).

b. Review the proposed evapotranspiration (ET) cover designs for RFETS. Review the performance assessment models and engineering calculations RFETS plans to implement in the cover design process for soil water balance, evapotranspiration, erosion, revegetation, etc.

c. Review baseline (current) environmental setting information such as site geomorphology (e.g. surface and slope stability) physical and hydraulic properties of borrow soils, existing vegetation, and burrowing animal habitat.

d. Determine key input parameters for engineering, performance assessment, and performance monitoring of the RFETS ET cover (e.g. soil water storage capacity, saturated hydraulic conductivity, monthly precipitation, etc).

e. Develop criteria for selecting analog sites for long-term changes in climate, geomorphology, soils, and ecology.

Expected Products/Results: Compilation of baseline ecological information for RFETS ET covers, cover design and performance standards, performance modeling and monitoring requirements, and analog site selection criteria.

Prerequisites: An agreement with RFETS to collaborate with the Principal Investigator of ASTD Proposal Number SC-17, "Rocky Flats Environmental Technology Site Proposal for Implementation of Evapotranspiration Covers."

Expected Duration: 3 months.

Task #2: Climate Change Investigation

Description: Perform the following activities:

a. Characterize modern climate for RFETS including historical meteorological records and response to historical changes in atmospheric circulation (e.g., El Nino and La Nina years). Obtain maps of modern climate for the region.

b. Review projected global/regional climate change scenarios and ranges of potential future climate states (temperature, precipitation, seasonality, extremes).

c. Search paleoclimate literature for ranges of past climate states that are analogous ranges of global/regional change scenarios.

d. Define key future climate states for direct input to performance modeling and monitoring

e. Define key future climate states for indirect (secondary) impacts on cover performance for input to analog site selection (e.g. what climate end states would most impact other performance processes such as erosion, soil development, plant community development, burrowing animal habitat, etc.).

f. Develop GIS layer indicating, regionally, where potential analog sites may exist representing key future climate states.

Expected Products/Results: Reasonable range of possible future climate states and extremes for Rocky Flats based on existing paleoclimate literature and global climate change models for input to (1) cover performance models and (2) analog site selection (Task 3).

Prerequisites: Task 1.

Expected Duration: 6 months

Task #3: Analog Site Reconnaissance

Description: Perform the following activities:

a. Acquire local/regional geologic maps, soil surveys, topographic maps, vegetation maps and floras, air photos, satellite imagery, etc. for the RFETS area and for analogs of future climate states.

b. Develop GIS layers for existing vegetation, geomorphology, and soils for the RFETS area and for areas analogous to future climate states.

c. Search literature for land use history and archaeological sites/resources that may provide chronological control for understanding rates of geomorphology/soil develop and ecological succession for the 1000-year design life of RFETS covers. Create land-use/archaeology GIS layers.

d. Use existing resources, the analog-site GIS, and selection criteria to locate and rank potential analog sites.

Expected Products/Results: GIS maps of locations to search for sites that are reasonable analogs of possible future ecological conditions on the RFETS ET covers.

Prerequisites: Tasks 1 and 2.

Expected Duration: 3 months

Task #4: Analog Site Characterization

Description: Perform the following activities:

a. Characterize hillslope settings analogous to the geometry and materials proposed for the RFETS ET covers. Develop a conceptual model and then characterize geomorphological processes that would likely have the greatest impact on the engineered cover. Characterize geomorphological settings exhibiting favorable attributes of long-term stability (e.g. rock/soil armored slope with a favorable soil water balance) that could be incorporated into the cover design.

b. Characterize analog-site soil profiles (natural and archaeological soil profiles if they exist) to identify pedogenic processes (e.g. bioturbation and soil structural development) that could impact the performance of the RFETS cover over its 1000-year design life. Measure key performance assessment parameters in analog soil profiles such as hydraulic conductivity and water storage capacity.

c. Characterize ecological analogs.

- Choose and characterize reference plant communities that represent the potential vegetation for the cover and that can be used as a revegetation target.

- Identify and rank types of secondary perturbations for the site such as fire, grazing, invasion of exotic species, cultivation, etc. Characterize vegetation chronosequences for key disturbances.

- Locate and characterize analogs of ecological responses to potential future climate states. Characterize key vegetation parameters impacting performance such as canopy cover, leaf area index, and root length density. Also characterize habitat for burrowing animals and impacts of burrows and tunnels on cover performance (e.g., effects on macropore flow and soil displacement).

Expected Products/Results:

- Baseline geomorphological and ecological data for input to the ET cover engineering and revegetation designs at RFETS.

- Soil (physical and hydraulic properties) and vegetation (plant community structure and ecophysiology) data from analog sites for input to soil water balance and erosion models as part of a long-term performance evaluation for the RFETS ET cover.

Prerequisites: Task 3.

Expected Duration: 12 months

Task #5: Incorporate Analog Site Data and Existing Alternative Cover Study

Description: Incorporate the analog site data and the existing alternative cover study results into the RFETS ET cover design process (see ASTD Proposal Number SC-17, "Rocky Flats Environmental Technology Site Proposal for Implementation of Evapotranspiration Covers."). Perform the following activities:

a. Use results of Tasks 1 – 4 to provide ET cover design recommendations including the feasibility of incorporating aspects of the technologies discussed on Form A: biointrusion barriers, rock/soil armoring, water balance designs, geomorphological geometry, and ecologically sustainable designs

b. Evaluate possible future changes in the condition of RFETS ET covesr based on characterization of natural analogs (Tasks 1-4).

c. Create input data files for long-term performance modeling of RFETS ET covers.

Expected Products/Results: Design and performance assessment data sets, recommendations, and technical assistance for RFETS ET covers.

Prerequisites: Tasks 1-4.

Expected Duration: 3 months

Technology/Technique Descriptions

Cover designs are needed that will contain buried wastes for hundreds to thousands of years, and do so while natural processes are acting to mobilize contaminants. This is an unprecedented engineering challenge. Current design approaches, which attempt to engineer barriers that block contaminant release processes such as water flux, erosion and biointrusion, have failed in the short term—the barriers degrade with time. DOE needs an alternative approach for designing, building and operating sustainable covers that mimic favorable elements of natural landscapes, which have already passed the test of time. This capability and target are closely linked to Capability and Target 4.1, "develop a toolbox .(e.g., models, natural analogs, guidance, etc.) to improve planning, decision making, designing, monitoring, maintenance".

Biointrusion Barriers.

Description: Barriers are needed that prevent burrowing and tunneling animals, and deep-rooted plants, from contacting and mobilizing subsurface contaminants or from disrupting critical cover layers. Physical and chemical barriers (e.g. subsurface rock or time-release herbicide layers) are necessary in some designs. Ideally, however, after thorough characterization of the local ecology, covers can be designed to accommodate plant and animal habitat without the need for physical or chemical barriers.

Current Maturity Level: Being applied – Design and construction of physical and chemical biointrusion barriers are well-documented and demonstrated. Some have been deployed. The prospect of accommodating plant and animal habitat in a design must be evaluated on a site-by-site basis.

Range of Applicability: In the long term, ecological development is inevitable on all covers.

Needed R&D: Need to:

1) Evaluate the performance of existing deployments.

2) Develop guidance or provide expert technical assistance to walk a designer through baseline ecological evaluations that are needed to design a cover that prevents biointrusion.

Sources/References:

Anderson, J.E., and A.D.Forman, 2002. The Protective Cap/Biobarrier Experiment: A Study of Alternative Evapotranspiration Caps for the Idaho National Engineering and Environmental Laboratory. STOLLER-ESER-46, S.M. Stoller Corporation, Idaho Falls, ID.

Bowerman, A.G., and E.D. Redente, 1998. Biointrusion of protective barriers at hazardous waste sites. J. Environ. Qual. 27 :625-632.

Hakonson, T.E., L.J. Lane, and E.P. Springer, 1992. Biotic and abiotic processes. In: C.C. Reith and B.M Thompson (eds.). Deserts as Dumps? The Disposal of Hazardous Materials in Arid Ecosystems (pp. 101-146).

Link, S.O., L.L. Cadwell, K.L Petersen, M.R. Sackschewsky, and D.S. Landeen, 1995. The Role of Plants and Animals in Isolation Barriers at Hanford, Washington. PNL-10788, Pacific Northwest National Laboratory, Richland, WA.

Suter, G.W., R.J. Luxmoore, and E.D. Smith, 1993. Compacted soil barriers at abandoned landfill sites are likely to fail in the long term. J. Environ. Qual. 22:217-226.

Waugh, W.J., and G.N. Richardson, 1997. Ecology, Design, and Long-Term Performance of Surface Barriers: Applications at a Uranium Mill Tailings Site, pp. 36-49. In: Barrier Technologies for Environmental Management, National Research Council, National Academy Press, Washington, D.C.

Rock / Soil Armoring (e.g., mimic desert pavements).

Description: Vegetation may be too sparse to stabilize soil covers in arid and semiarid regions, especially on steeper side slopes. UMTRA design guidance specifies highly durable rock on slopes as a means of controlling erosion. However, by reducing evaporation and increasing soil water storage, rock layers increase water infiltration, which can lead to root intrusion and an increase in the hydraulic conductivity of underlying soil layers. Layers of rock and soil mixed together can control erosion and also enhance plant growth and water extraction (evapotranspiration), much like desert pavements and vegetated slide rock. By allowing safe placement of waste under side slopes, covers armored with rock, soil and plants will have significantly smaller footprints and cost less.

Current Maturity Level: Effects of gravel admixture layers on soil loss, plant growth and soil water balance have been demonstrated and designs have been deployed at a few sites. Analogs of the stability of thick admixture layers of rock, soil, and vegetation for use on side slopes have been investigated, but engineered designs have not been attempted.

Range of Applicability: Arid and semiarid sites, especially sites requiring sloped covers.

Needed R&D: Need to:

1) Evaluate the stability, soil water balance, and ecology of existing deployments having gravel admixture designs on the top slope.

2) Design (mimic) and test the performance (soil water balance and stability) of vegetated rocky slopes.

3) Develop guidance or provide expert technical assistance to help design rock/soil layers.

Sources/References:

Sackshewsky, M.R., C.J. Kemp, S.O. Link, and W.J. Waugh, 1995. Soil water balance changes in engineered soil surfaces. Journal of Environmental Quality 24:352-359.

Smith, G.M., W.J. Waugh, and M.K. Kastens, 1997. Analog of the long-term performance of vegetated rocky slopes for landfill covers, pp. 291-300. In: Tailings and Mine Waste '97, A.A. Balkema, Rotterdam.

Waugh W.J., M.E. Thiede, and D.J. Bates, 1994. Plant cover and water balance in gravel admixtures at an arid waste-burial site. Journal of Environmental Quality 23:676-685.

Winkel, V.K., B.A. Roundy, and J.R. Cox, 1991. Influence of seed microsite characteristics on grass seedling emergence. Journal of Range Management 44:210-214.

Water balance designs (evapotranspiration covers, capillary barriers, water shedding covers).

Description: Arid and semiarid ecosystems often return all precipitation to the atmosphere via evapotranspiration. Cover designs can mimic these ecosystems. Recharge is limited if designs use thick, fine-textured soil covers that store precipitation in the root zone where it is seasonally removed by evapotranspiration. The water-storage capacity is increased when the fine-textured soil "sponge" is placed over a coarse sand or gravel layer creating a capillary barrier. Unless the water content of the soil layer exceeds its storage capacity, downward water movement is inconsequential. At humid sites, where precipitation exceeds evapotranspiration, recharge can be prevented by shedding water to the perimeter of the cover. Then evapotranspiration can remove the lesser amounts of water that infiltrate the soil.

Current Maturity Level: Evapotranspiration covers with and without capillary barriers and water shedding covers have been demonstrated in large lysimeters (field tests), and a few have been deployed. Evaluations of long-term performance using analogs is underway.

Range of Applicability: Arid, semiarid, and humid sites requiring long-term covers.

Needed R&D: Many water balance cover prototypes and demonstrations have been installed, and there have been a few deployments, but few have been monitored long enough for vegetation to mature. Need to

1) Resume performance evaluations of field installations with mature vegetation,

2) Test a water-shedding design made of natural materials at humid sites,

3) Develop guidance for projecting long-term performance of cover systems that links natural analogs with field tests and probabilistic modeling, and

4) Develop long-lasting monitoring tools that target early-warning of potential changes in system performance; methods for remote sensing (large-scale measurement) of natural indicators of change (e.g. phytomonitoring) are needed.

Sources/References:

Anderson, J.E., and A.D.Forman, 2002. The Protective Cap/Biobarrier Experiment: A Study of Alternative Evapotranspiration Caps for the Idaho National Engineering and Environmental Laboratory. STOLLER-ESER-46, S.M. Stoller Corporation, Idaho Falls, ID.

Dwyer, S.F., 1998. Alternative covers pass the test. Civil Engineering, September, pp. 50-52.

Gee, G.W. and S.W. Tyler (eds.), 1994. "Symposium: Recharge in Arid and Semiarid Regions," Soil Science Society of America Journal 58:5–72.

Link, S.O., N.R. Wing, and G.W. Gee, 1994. "The Development of a Permanent Isolation Barrier for Buried Wastes in Cool Deserts: Hanford, Washington," Journal of Arid Land Studies 4:215–224.

O'Donnell, E., R.W. Ridky, and R.K. Schultz, 1994. Control of Water Infiltration into Near-Surface, Low-Level Waste-Disposal Units in Humid Regions. pp. 295-324. In G.W. Gee and N.R. Wing (eds.), In-Situ Remediation: Scientific Basis for Current and Future Technologies. Battelle Press, Columbus, OH.

Ward, A. L., and G. W. Gee. 1997. "Performance Evaluation of a Field-Scale Surface Barrier". J.Environ. Qual. 26:694-705.

Waugh, W.J., 2002. Monticello Field Lysimetry: Design and Monitoring of an Alternative Cover. Proceedings of the Waste Management 2002 Symposium, University of Arizona, Tucson, Arizona, February 25-28, 2002.

Waugh, W.J., K.L. Petersen, S.O. Link, B.N. Bjornstad, and G.W. Gee, 1994. Natural Analogs of the Long-term Performance of Engineered Covers, pp. 379-409. In G.W. Gee and N.R. Wing (eds.), In-Situ Remediation: Scientific Basis for Current and Future Technologies. Battelle Press, Columbus, OH.

Geomorphological Geometry

Description: The design and construction of a long-term cover can be viewed as the formation of a new geomorphic landform with a new soil parent material. Pedogenesis and surficial geomorphic processes will inevitably alter the original engineered character of the cover, possibly impacting both the short- and long-term performance of the cover. Sustainable designs will mimic geologically stable surfaces, for example, by designing drainage networks into a cover based on geologic conditions similar to the landfill site.

Current Maturity Level: Many deployed covers have drainages to channel runoff water away from disposal cells. The UMTRA program has investigated analogs of stable slopes, and development of guidance for characterizing natural analogs of geologically stable surfaces is underway, but these types of designs have not been tested or deployed.

Range of Applicability: All cover designs.

Needed R&D: Need to:

1) Develop written guidance and technical assistance for characterizing geomorphic and pedogenic processes at a landfill site based on input from geologists and soil scientists

2) Field test alternative designs that incorporate drainage networks into a cover.

Sources/References:

Smith, G.M., W.J. Waugh, and M.K. Kastens, 1997. Analog of the long-term performance of vegetated rocky slopes for landfill covers, pp. 291-300. In: Tailings and Mine Waste '97, A.A. Balkema, Rotterdam.

Rhode, D., S. Sharpe, E. McDonald, and T. Bullard, 2001. FY 2002 Work Plan for Natural and Archaeoligical Analog Studies at the CRECLA Waste Disposal Cell, Monticello, Utah: Effects of Climate Variability and Soil-Geomorphic Processes On Long-term Cover Performance. Desert Research Institute, Reno, NV.

Waugh, W.J., K.L. Petersen, S.O. Link, B.N. Bjornstad, and G.W. Gee, 1994. Natural Analogs of the Long-term Performance of Engineered Covers, pp. 379-409. In G.W. Gee and N.R. Wing (eds.), In-Situ Remediation: Scientific Basis for Current and Future Technologies. Battelle Press, Columbus, OH.

Ecologically Sustainable Designs

Description: Ecological development on covers is inevitable. Current engineering approaches fail to consider either the deleterious or beneficial effects ecological processes may have on the long-term performance of covers. Seeding of monocultures or low-diversity vegetation on engineered covers is common. Instead, revegetation should attempt to emulate the structure, function, diversity, and resiliency of reference ecosystems.

Current Maturity Level: The principles and practices of restoration ecology and mine land reclamation are very well developed but have not been fully integrated into cover design process.

Range of Applicability: All cover designs

Needed R&D: Develop written guidance and technical assistance from restoration ecologists and reclamation specialists to accelerate integration of these techniques into the engineering of long-term covers.

Sources/References:

Allen, E.B. (ed.). 1988. The Reconstruction of Disturbed Arid Lands: An Ecological Approach. AAAS Selected Symposium 109, American Association for the Advancement of Science, Washington, D.C.

Anderson, J.E., and R.S. Inouye, 2001. Landscape-scale changes in plant species abundance and biodiversity of a sagebrush steppe over 45 years. Ecological Monographs 71:531-556.

Barnhisel, R.I., R.G. Farnmody, and W.L. Daniels. 2000. Reclamation of Drastically Disturbed Lands. Agronomy No. 41, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin.

Covington, W.W., and L.F. DeBanco (eds.). 1994. Sustainable Ecological Systems: Implementing an Ecological Approach to Land Management. USDA Forest Service General Technical Report RM-247, Rocky Mountain Forest and Range Experiment Station, U.S. Department of Agriculture, Fort Collins, CO.

Link, S.O. 2001. FY 2002 Work Plan for a Field Demponstration of Baseline Ecological Studies at the Monticello, Utah Superfund Site: Revegetation Design, Performance Monitoring, and Effects of Ecological Change On Long-term Cover Performance. Washington State University-TriCities, Richland WA.

Phytoremediation Caps.

Description: A phytoremediation cap is a type of "smart storage", a system that integrates containment and treatment. Plants growing in a soil cover are used to manipulate hydraulic gradient and prevent recharge as with ET caps (containment), but also to stabilize or detoxify the contaminants (treatment). The idea is that, waste stabilization or treatment will shorten the necessary period of isolation or containment.

Current Maturity Level: Phytoremediation is a developing technology but with several deployments. Phytoremedation caps are primarily conceptual; field tests and demonstrations are needed.

Range of Applicability: Where both phytoremediation and hydraulic manipulation are needed.

Needed R&D: Need to:

1) Survey applicability of phytoremediation caps within the DOE complex.

2) Perform field tests of the installation and performance of phytoremediation caps

3) Develop methods to monitor treatment to determine when containment is no longer needed.

Sources/References:

Looney, B. (ed.), 2002. Technical Targets: A Tool to Support Strategic Planning in the Subsurface Contaminant Focus Area. WSRC-RP-2002-00077, Westinghouse Savannah River Company, Aiken, SC.

U.S. Department of Energy, 2000. Proceedings from the Workshop on Phytoremediation of Inorganic Contaminants, November 3 – December 2, 1999, Argonne National Laboratory, Chicago, Illinois. INEEL/EXT-2000-00207, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID.

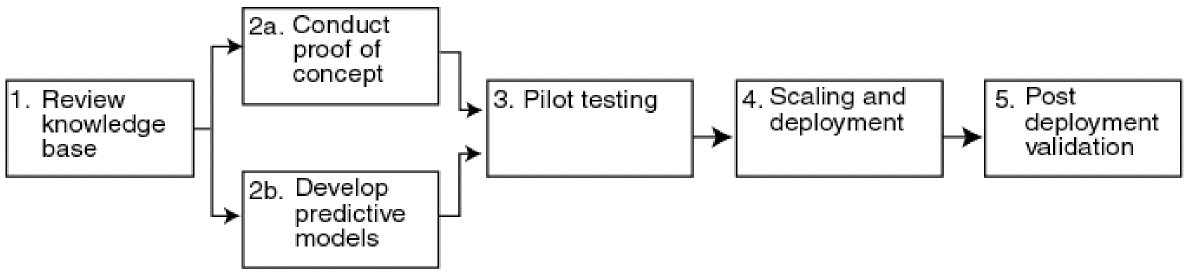
U.S. Environmental Protection Agency, 2000. Introduction to Phytoremediation. EPA/600/R-99/107, National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Waugh, W.J., and E.P. Glenn, 2002. Phytoremediation of Nitrogen Contamination in Subpile Soils and in the Alluvial Aquifer at the Monument Valley, Arizona, Uranium Mill Tailings Site. GJO-2002-312-TAR, UMTRA Ground Water Research Project, U.S. Department of Energy Grand Junction Office, Grand Junction, CO.

TARGET 2.2B

Deploy subsurface containment systems that mimic natural processes and accommodate environmental change.

Capability Enhancement Pathway



Pathway Task Descriptions

Task #1: Review Existing Knowledge Base.

Description: This will include a review of the existing literature, discussions with project Principal Investigators, and discussion with site managers that have LTS needs. Information developed from current site remediation activities such as Rocky flats or Fernald should coordinated, recognizing the limitations of each site on applicability to other sites. The cost is expected to be relatively high for this review because there are a wide variety of potential technologies, some of which are very new and others more established, with a corresponding variation in availability of information.

Expected Products/Results: The product of the review will be an understanding of the status of the need for research in this area, current maturity, and gaps in the science needed to develop this technology.

Prerequisites: All that is needed to initiate this task is a decision to invest in the research area.

Estimated Duration: 6 months

Task #2a: Conduct Proof of Concept.

Description: Laboratory scale (or garden scale) testing of containment technologies theories (on simulants most likely), analysis or results, efficiency improvements, reformation to workable systems. Owing to the need to deal with growing seasons, this task is estimated to last at least two years. However, much can be learned in the first year, which could allow for initiation of subsequent tasks during year two if determined to be desirable. Some techniques will require little if any bench scale testing as they are already fairly mature techniques thus reducing overall costs.

Expected Products/Results: In coordination with Task 2b the product should be an understanding of performance at small scale and under idealized conditions.

Prerequisites: Completion of the Task 1 studies to allow definition of the knowledge base and the ideas to test for verification of concept.

Expected Duration: 24 months

Task #2b: Develop Predictive Models.

Description: Merge theory with experimental results from Task 2a to guide this task, and to provide guidance for Task 2a. Synergism is the key for these two tasks. This task runs concurrently with Task 2a. Model development can largely be completed in year one, except for those technologies utilizing phyto based techniques, in that case the models should be refined in year two. Models are not expected to be overly complex and can draw on existing models as a foundation with fine tuning based upon small scale studies conducted in Task 2a.

Expected Products / Results: In coordination with Task 2a the product should be an understanding of performance at small scale and under idealized conditions. However, the modeling component should also allow for evaluation of the effect of changes in conditions governing performance of the systems.

Prerequisites: To allow definition of the knowledge base and development of the concept of system configuration and thus the modeling capability necessary.

Expected Duration: 24 months

Task #3: Pilot Testing.

Description: Scale up from bench (garden) studies, add more realism by using real waste, but still keep some idealism for the capability to work. The duration should allow for several growing seasons and a longer duration of maintenance and data collection are strongly recommended. Costs will be highly dependent on the size of a field test location, which directly impacts construction costs and also has a direct impact on monitoring, maintenance and operations costs.

Expected Products/Results: The end result will be a scaled up proof of concept that includes more real-world issues and uncertainties, heterogeneities, etc.

Prerequisites: Completion of the Task 2a and 2b studies with good results, funding buy-in to the viability of the concept, a site to use for field-testing, and regulatory approval.

Estimated Duration: 24 months

Task #4: Scaling and Deployment.

Description: Engineering analyses, cost analysis, building of systems, licensing to contractors, secure test site, attain regulatory approval, and test on real contaminants. The task duration must allow for several growing seasons. Longer duration of maintenance and data collection are strongly recommended particularly for this field trial. It seems likely that longer term monitoring will be required to obtain regulatory approval in any event. Cost will be highly dependent on the size of a field test location, which directly impacts construction costs and also has a direct impact on monitoring, maintenance and operations costs.

Expected Products / Results: The expected product is a successful demonstration project with knowledge gained regarding limitations of the system and needs to make changes to fine-tune future deployments.

Prerequisites: Successful pilot level testing in Task 3, regulatory buy-in, deployment site, and finding buy-in.

Estimated Duration: 24 or 36 months

Task #5: Post Deployment Validation.

Description: Monitor system, understand maintenance and repair issues, operational costs and issues, complete performance comparison with alternative technologies, and publish results to widely distribute knowledge gained, including the preparation of guidance documents. Longer term monitoring is mainly in the area of confirmation of models and findings, and thus is utilized to 'fine-tune" earlier conclusions. As no new construction is needed, the work is mainly data collection and analysis and maintenance.

Expected Products/Results: Adoption of technique as one of a group of potential long term remediation and stewardship strategies. Regulatory acceptance as a viable technology (system) that is no longer considered experimental.

Prerequisites: Successful site deployment under Task 4.

Estimated Duration: 12 to 24 months

Technology/Technique Descriptions

Geologic material based leachate collection and leak detection systems

Description: While the use of geosynthetic media has been common in recent years, geologic materials i.e. gravel and sand have been utilized in projects with long design lives like the Fernald LTDF. There remains room for some additional study to fine-tune and refine the capability to reduce long-term failures by clogging.

Current Maturity Level: Being applied

Range of Applicability: Municipal solid waste (MSW), UMTRA, Low-level waste, mixed waste, hazardous waste.

Needed R&D: Conduct a forensic study of the performance of systems that have been in use. Much of the needed data might come from existing MSW and hazardous waste sites outside of the complex.

Passive-reactive barriers and enhanced biological treatment barriers

Description:

Current Maturity Level: Being applied. Some applications in the field are in place and functioning.

Range of Applicability: Relatively wide, mainly utilized with organic contaminants to date, could also be useful with inorganic materials, particularly metals and mixed wastes.

Needed R&D: Bench and pilot testing form specific contaminants and waste mixtures. Further research is needed for inorganic contaminants.

Slurry walls, grout curtains, bottom seals and enhanced barrier clogging

Description:

Current Maturity Level: Being applied. Relatively mature except for enhanced barrier clogging which is in an early stage of development. In-situ placement of horizontal barriers needs additional research, but could draw on use in other industries such as utility installation.

Range of Applicability: Used for a wide range of wastes and settings.

Needed R&D: Research is needed on sustainability over time, and on application of systems with primary reliance on native/natural geologic materials and microorganisms. Study is also needed regarding the applicability of in-situ horizontal barrier construction. This should utilize information on direction drilling technologies.

Deep-rooted phyto-hydraulic control and pumping for hydraulic control

Description:

Current Maturity Level: Being applied

Range of Applicability: Wide range of use. Particularly applicable to vadose zone.

Needed R&D: Testing and application to optimize species selection and related maintenance issues to sustain species: i.e. fires for prairies, enhanced symbiosis to promote natural sustainability

Frozen soil barriers

Description:

Current Maturity Level: Under Development. Mature technology for other applications such as tunnel and shaft support. Has not been applied to contaminant migration problems, although it has been tested as part of the SITE Demonstration Program at Oak Ridge National Laboratory. .

Range of Applicability: Wide variety of contaminants and wastes. May be limited in long term applications due to energy requirements

Needed R&D: Further field tests are necessary to more completely evaluate this technology.

Sources/Resources:

http://www.clu-in.org/products/site/ongoing/demoong/arctic.htm - EPA technology profile of the "Cryogenic Barrier", written before testing began.

http://www.wpi.org/Initiatives/init/oct97/ - "Will frozen barrier stop plume in its tracks?" (1997)

http://www.ct.ornl.gov/stcg/nls97.htm - "Cryogenic Barrier is Being Installed and Tested on a Superfund Site at ORNL" (summer 1997)

Capillary barriers

Description:

Current Maturity Level: Under development. Used in disposal facility covers, and in underdrain systems. Principle is widely used in building construction for moisture barriers below concrete slabs on grade. Use in horizontal or vertical barriers in contaminant control is less mature.

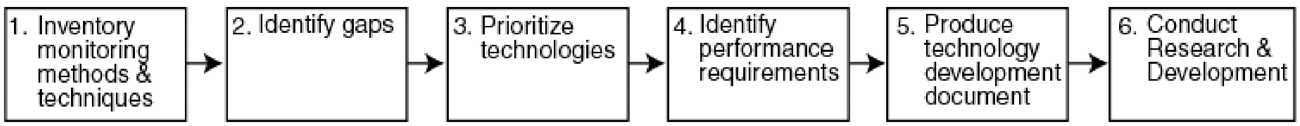
Range of Applicability: Relatively wide range of wastes, and contaminants, particularly applicable in the vadose zone.

Needed R&D: Technical basis can readily be adapted from other applications of this technique. Physical principals are basic and straightforward. Demonstration projects are needed. Development of technology guidance documents are desirable as well.

TARGET 3.1A

Develop technology to fill 30 percent of identified gaps.

Capability Enhancement Pathway



Pathway Task Descriptions

Task #1: Inventory of monitoring methods and techniques for all pathways

Description: Collection and study of existing lists and descriptions of monitoring methods and techniques for air, surface water, vadose zone, groundwater, and manmade structures. Examples of existing lists include EPA, DOE-EM; joint EPA, DOE and DoD in Integrated Technology Research and Deployment; Characterization, Monitoring and Sensor Technologies. In addition, many of the sites have compiled lists of monitoring methods being used. These lists will be used to determine costs, detection levels, long-term performance, and constraints on deployment.

Expected Products/Results: Report detailing existing technologies, costs, detection levels, long-term performance, and constraints on deployment.

Prerequisites: Existing lists of monitoring methods

Estimated Duration: 3 months

Task #2: Identify Gaps

Description: Based on site and regulatory input identify critical high priority parameters that need to be monitored. Determine how well these parameters can be monitored with existing technologies or with modifications of existing technologies, and identify parameters that cannot be monitored with existing techniques.

Expected Products/Results: Gaps that will be identified include upgrades in existing technologies and new technologies that can be developed to measure the high priority parameters.

Prerequisites: Inventory of monitoring technologies; high priority parameters from site input and regulatory input; performance of existing monitoring technologies

Estimated Duration: 3 months

Task #3: Prioritize technologies by cost/risk/uncertainty for different sites and time frames

Description: Use cost and application data from task #1 with the priority lists from task 2 to rank selected technologies for development or upgrading. The prioritization will be based on reduction of cost, risk, and uncertainty for different sites and time frames (e.g. long-term stewardship for early closure sites starting in 2008 and for following closure sites that start in 2030).

Expected Products/Results: List of prioritized technologies by cost/risk/uncertainty for different sites and time

Prerequisites: Cost results from task #1, priority parameters from task #2; information on risk and uncertainty related to these parameters for the different sites.

Estimated Duration: 2 months

Task #4 Identify performance requirements

Description: Define the metrics and capabilities that are the targets for specific sensor development. Ensure that the upgraded or newly developed technology can meet the performance requirements.

Expected Products/Results: Performance criteria for upgraded or newly developed technologies

Prerequisites: Results from tasks #1, 2, and 3.

Estimated Duration: 2 months

Task #5: Develop compelling document for technology development

Description: Produce a white paper describing the inventory of existing techniques, the gap analysis, the prioritization, the performance requirements for upgraded and newly developed technology. These technologies address high priority needs of the end users and regulators. Initial analysis of the costs, uncertainty, and risk benefits will be included. In addition, a short succinct presentation will be developed and disseminated that portrays the important aspects of all these components.

Expected Products/Results: White paper and short presentation

Prerequisites: Results from tasks #1, 2, 3, and 4.

Estimated Duration: 2 months

Task #6: Conduct research and development

Description: Prepare a targeted call for proposals and select projects focused on identification and testing of a technologies that meet the requirements of Tasks 4 and 5. Review and select proposals for funding. Track R&D.

Expected Products/Results: Proven technologies that can be proposed to the regulators for long-term stewardship of a site

Prerequisites: Results from tasks #1, 2, 3, and 4

Estimated Duration: 60 months

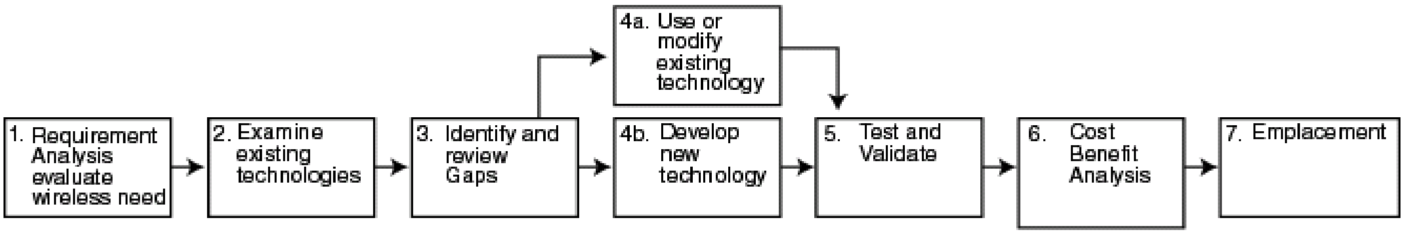
Technology/Technique Descriptions

None identified

TARGET 3.1B

Ten percent of sensor arrays in field can deliver data wirelessly from subsurface.

Capability Enhancement Pathway



Pathway Task Descriptions

Task # 1: Requirement Analysis

Description: Task 1 aims to determine the requirement that will be needed for applying wireless technologies. Task 1 will review the regulatory framework for monitoring by state, local and federal regulators. In addition, task 1 will develop the framework for conducting a technology assessment in task 2.

Expected Products/Results: The expected result from task 1 is an outline of the regulatory framework for monitoring techniques.

Estimated Duration: 3 months

Task # 2: Examine existing technologies

Description: Task 2 will examine the state of the art and science for wireless technologies. Task 2 aims to define what technologies are currently available and how have they been utilized. Technologies will be categories according to application, description, developmental state, cost, and feasibility.

Expected Products/Results: The expected result is a report that documents wireless technologies.

Prerequisites: Task 1 framework

Estimated Duration: 6 months

Task #3: Identify and review gaps

Description: Task 3 aims to identify and review gaps in the current state of the art and science in wireless technologies. Wireless technologies will be prioritized with respect to R and D needs. Technologies will be categories with regards to existing, modifications, or developmental.

Expected Products/Results: An RFP will be developed from the gap analysis that focuses on applied and basic research.

Prerequisites: Task 2

Estimated Duration: 3 months

Task #4a, b: Use existing, modify existing or develop new technologies

Description: Task 4 aims to utilized existing technology, modify existing technology or develop new technology that use wireless technology. Implementation of existing technology and modification of existing technology will encompass applied research which will be aimed at immediately impacted existing DOE sites. In addition, basic research will be conducted to develop new wireless technologies developed. (Note: modification and implementation of existing sensors should take two years where the development on new technologies will take 3 years). to

Expected Products/Results: The results of task 4 include the implementation of existing wireless technologies and the development of new wireless sensors.

Prerequisites: Task 1-3

Estimated Duration: 36 months

Task # 5 Test and validate

Description: Task 5 aims to test and validate wireless sensors. This task will involve the implementation of wireless sensors into DOE facilities. DOE will initiate a field implementation and testing program at various sites to determine the short-term performance of the sensors. Sensors will be monitored for long-term (10 years or greater) performance. For existing sensors, at the conclusion of task 5, there will be three years of performance data.

Expected Products/Results: The results of this task will include the implementation of existing sensors, modification of existing sensors, and development of new sensors.

Prerequisites: Task 4

Estimated Duration: 12 months

Task #6: Cost benefit analysis

Description: Task 6 aims to develop a cost-benefit analysis of wireless sensors and compare it to existing techniques for transferring data. Cost benefit analysis will compare and contrast wireless sensors to non wireless sensors with regards to cost, performance, and ease of utilization.

Expected Products/Results: A document will be developed on the CBA of wireless techniques.

Prerequisites: Task 1-5

Estimated Duration: 6 months

Task #7: Emplacement

Description: Task 6 will establish an emplacement guideline and protocol for wireless technologies.

Expected Products/Results: Guideline

Prerequisites: Task 1-5

Estimated Duration: 12 months

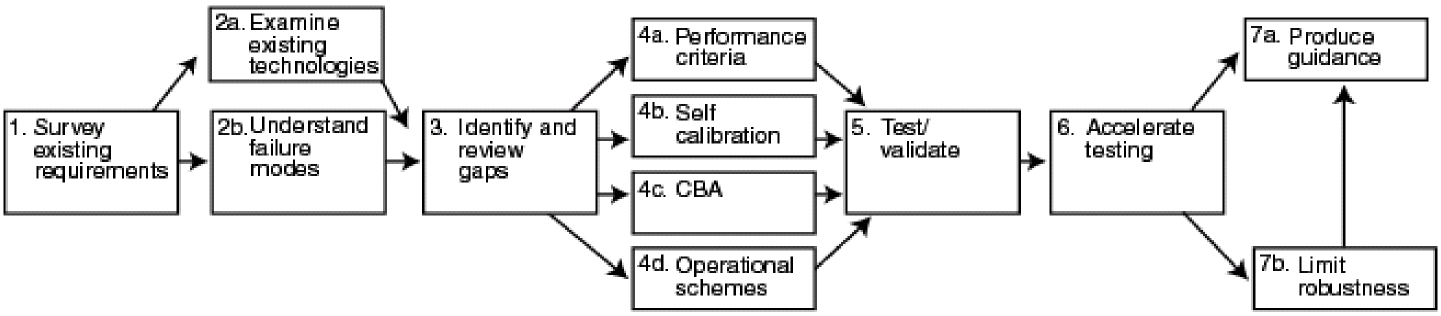
Technology/Technique Descriptions

None identified

TARGET 3.1C

Ensure that, 30 years out, 50 percent of sensors still meet their performance objectives.

Capability Enhancement Pathway



Pathway Task Descriptions

Task # 1 Survey existing requirements

Description: The goal of task one is to survey the existing requirements that would assure that 30 years out 50% of the sensors are still meet their original goal. Existing requirements would include federal, state and local requirements for long term monitoring where sensors can be utilized. In addition, a survey will be conducted of existing DOE facilities to gain an understanding of what types of monitoring technologies are currently utilized to establish the current use of techniques and technologies. A framework for assessing failure will be developed.

Expected Products/Results: A survey will be developed of existing requirements and currently used techniques and technologies.

Estimated Duration: 3 months

Task # 2a, 2b: Examine existing technologies and establish failure modes

Description: Task 2 will examine the state of the art and science for monitoring technologies. Task 2 aims to define what technologies are currently available and how have they been utilized. Technologies will be categories according to application, description, developmental state, cost, and feasibility. The failure modes, advantages and disadvantages will also be established.

Expected Products/Results: The expected result from task 2 is a document that outlines the failure modes for various monitoring technologies.

Prerequisites: Task 1

Estimated Duration: 6 months

Task # 3 Identify and review gaps

Description: Task 3 aims to identify and review gaps in the current state of the art and science in technologies. Failure modes will be prioritized with respect to R and D needs. Technologies will be categories with regards to existing, modifications, or developmental to reduce long term failure.

Expected Products/Results: A document will be developed that outlines the failure modes of monitoring technologies.

Prerequisites: Task 2

Estimated Duration: 3 months

Task # 4a, 4b, 4c, 4d: Performance, calibration, operational schemes, and CBA

Description: Task 4 aims to develop performance criteria, calibration requirements, operational schemes, and cost benefit analysis for reducing failure of sensor arrays. Performance criteria will be developed by reviewing regulatory requirements, establishing performance goals, and quantifying existing technologies performance data. Calibration requirements for the sensor arrays will also be established where sensor arrays will aim to incorporate self calibrating sensors. Operational schemes and approaches will also be reviewed. Cost benefit analysis will compare and contrast wireless sensors with regards to cost, performance, failure potential, longevity and ease of utilization.

Expected Products/Results: A performance assessment document on sensor technology will be developed. A protocol on sensor array configuration and implementation to reduce the risk of sensor failure will also be developed.

Prerequisites: Task 1-3

Estimated Duration: 18 months

Task # 5 Test and validate

Description: Task 5 will test and validate the implementation of the guidance on reducing failures in sensors. The protocol developed in task 4 will be tested at various DOE facilities.

Expected Products/Results: Performance data will be obtained.

Prerequisites: Task 4

Estimated Duration: 12-36 months

Task # 6 Accelerate testing

Description: Task 6 will perform accelerated testing on the sensor configurations. Accelerated testing may include increased temperature, gravitational acceleration, or pressure.

Expected Products/Results: Predictions of long term performance

Prerequisites: Tasks 1-5

Estimated Duration: 12 months

Task # 7 Guidance Document

Description: Task 7 will produce a guidance document that outlines performance criteria, the protocol for designing sensor arrays to reduce failure, performance data on sensor array configurations, and cost benefit analysis.

Expected Products/Results: Guidance document

Prerequisites: Tasks 1-6

Estimated Duration: 12 months

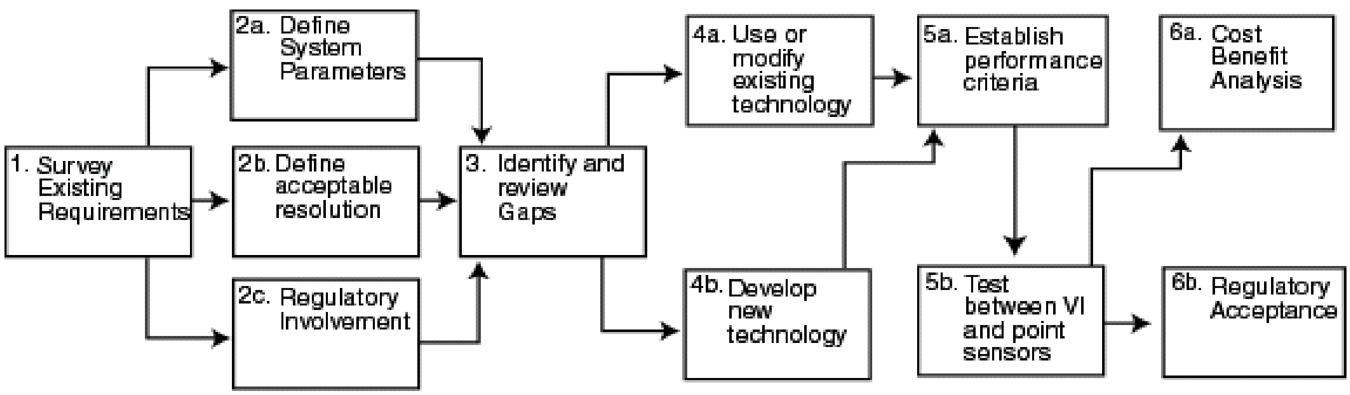
Technology/Technique Descriptions

None identified

TARGET 3.1D

Increase application of volume integrating methods, including non-invasive techniques, to 10 percent application in areas such as soil moisture and leak detection.

Capability Enhancement Pathway



Pathway Task Descriptions

Task # 1 Survey existing requirements

Description: The goal of task one is to survey the existing requirements that would allow for the utilization of volume integrating techniques that include non-invasive. Existing requirements would include federal, state and local requirements for long term monitoring where sensors can be utilized. In addition, a survey will be conducted of existing DOE facilities to gain an understanding of what types of monitoring technologies are currently utilized to establish the current use of point versus volume integrating techniques and technologies.

Expected Products/Results: The expected product will be a report that catalogues the type of sensors utilized at current DOE facilities.

Estimated Duration : 2 months

Task # 2a, 2b, 2c: Define regulatory involvement, system parameters, and resolution

Description: Task 2 aims to define the regulatory involvement, system parameters and resolution for the application of volume integrating techniques. First, a review must be conducted of state and federal regulations that will govern the design of the monitoring approach. Upon reviewing the regulatory requirements, system parameters will be established which can utilize volume integrating techniques. Next, the resolution of the parameters will be established to define how the sensors will measure changes in the parameter in contrast to point sensors that measure absolute values.

Expected Products/Results: This task will produce a report on the potential application of volume integrating techniques at DOE facilities.

Prerequisites: Task 1

Estimated Duration : 6 months

Task #3: Identify and Review Gaps

Description: Task 3 aims to identify and review gaps in the design, development, implementation, and assessment of volume integrated sensors. This task will analyze the current use of volume integrating techniques, determine the state of art in volume integrating techniques, and determine where and how it can be incorporated. In addition, this task will outline the research needs.

Expected Products/Results: A report will be generated that outlines the state of the art for existing technologies, current uses, and research needs for volume integrating techniques and technologies. In addition, an RFP will be developed for task 4.

Prerequisites: Task 1 and 2.

Estimated Duration : 4 months

Task # 4a, 4b: Use existing, modify existing or develop new technologies

Description: The goal of task 4 is to utilize existing, modify existing or develop new technologies that utilize volume integrating techniques. Applied research will be conducted to implement existing technologies and to modify existing technologies to utilize volume integrating techniques. In addition, basic research will be conducted to develop new volume integrating techniques for application. (Note: modification and implementation of existing sensors should take two years where the development on new technologies will take 3 years).

Expected Products/Results: The expected results include the development of new technologies, application of existing technologies, and modification of existing techniques.

Prerequisites: The request for proposals and Task 1-3 must be developed.

Estimated Duration : 24-36 months

Task # 5a, 5b: Establish performance criteria and test difference between VI and Point sensors

Description: Task 5 aims to establish performance criteria and test the difference between VI and point sensors. VI sensors will be implemented at DOE sites in conjunction with point sensors. DOE will initiate a field implementation and testing program at various sites to determine the short-term performance of the sensors. Sensors will be monitored for long term (10 years or greater) performance. For existing sensors, at the conclusion of task 5, there will be three years of performance data.

Expected Products/Results: The results of this task will include the implementation of existing sensors, modification of existing sensors, and development of new VI sensors.

Prerequisites: The R&D phase in task 4 must be accomplished.

Estimated Duration : 12 months

Task # 6a, 6b: Cost Benefit and Regulatory Acceptance

Description: Task 6 involves developing a cost benefit analysis of the sensor techniques that were developed. CBA will categories the pros and cons of each technique based on performance, applicability, and cost. In addition, regulatory acceptance will be sought. To steward regulatory acceptance, the regulatory community must be involved in the developmental process. To foster regulatory acceptance, members of the regulatory community should be involved in development of Task 1-3.

Expected Products/Results: An interagency guidance document will be produced that quantifies the cost-benefits of the different volume integrating techniques and technologies.

Prerequisites: Task 1-5.

Estimated Duration : 12 months

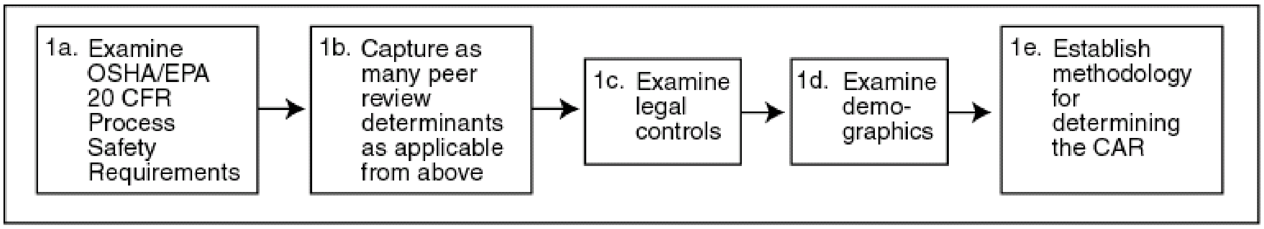
Technology/Technique Descriptions

None identified

TARGET 3.2

Provide decision aids to help monitoring system planners and site stewards define monitoring system targets (hazards or surrogates), thresholds, and action limits by incorporating defensible, credible methodologies for establishing the site-specific parameters for environmental exposures and for occupational and non-occupational human exposures.

Capability Enhancement Pathway



Pathway Task Descriptions

Task # 1a, 1b, 1c, 1d, 1e: Establish methodology for determining the Community At Risk (CAR)

Description: The objective of this task is to establish criteria for health exposure for occupational and non-occupational personnel categories. Lasting and scientifically defensible criteria must be developed to provide action levels/warning levels of target contaminants in order for proper protective response by persons within the CAR.

There will, for purposes of this task, be two separate groups of individuals. They are the occupational (Passive Systems) and the non-occupational (Active Systems). The occupational group of individuals are those who have an authorized permission to enter the site barriers for reasons of maintenance, inspection, or for cultural visitations, etc.

The occupational population will be governed, monitored and tracked for exposure based upon the regional, State, federal, or public entity having jurisdiction. However, the exposure levels for off-stie (non-occupational) chemicals and radiological exposures will fall under the jurisdiction of the various state health agencies, such as the ecology or health departments, which may or may not have promulgated regulations dealing with community exposure levels derived from the site source term. Further, a large number of chemicals, (inorganic and organic) are listed within the CFR and the capability to chose a credible targetor targets is simplified. The various state standards dealing with occupational exposure levels for both radiological and non-radiological materials are continually updated to reflect current epidemiological and toxicological information and are likely to remain in effect through time. As a result, there is no need to augment, change or add any additional criteria for exposure to chemical, biological or radiological materials for the occupational segment of the population.

The non-occupational or CAR population is composed of the personnel who reside or routinely visit the areas adjacent to the **Non-Static** boundaries of the site. There are no regulations for 24 hour or domesticated based chemical exposure over a prolonged period of time to small quantities of contaminants which eminate from the site residue. However, some target agents can be derived from the mix of potential contaminants that can be credibly liberated and mechanically transported to the CAR and thus detected. Very low concentrations of military weapon chemicals are being remotely detected in the parts-per-billion range. Some professional organizations have published guides for some very limited contaminants. Although these guides have gone through some level of peer review, the likelihood of their continuing existence over even decades is slim at best. Also, the universe of chemicals that these professional groups have studied (to date) is rather limited. As a result, those guides may not be updated nor expanded in scope as a result of an association's change of focus or eventual demise[1]. Several other lasting options that could provide a methodology that could be used to establish non-occupational threshold limits could include bridging American Industrial Hygience Association efforts with the American National Standards Institute (ANSI) or the State Governors' Association.

OSHA would not be involved in the active system's (CAR) target limit establishment and the state or local health or environmental departments (those charged with responding to concerns and complaints within the non-occupational environment) would need some criteria that could withstand technical scrutiny in order to adequately respond and mitigate community (CAR) concerns.

This is not a simple task: comments have been received by the workgroup from published and reputible engineers/industrial hygienists regarding the employment of fractionally reduced OSHA exposure levels, with no technical basis, as acceptable residential environmental exposure levels. In some cases, commenters regarded the application of this simplified, across-the-board reduction as bordering on malpractice. Assuming local or state agencies are responsible, some meaningful criteria must be provided which can be incorporated into the LTS program. Clear recognition must be made that the non-occupational population should be protected.

Expected Products/Results: Develop a methodology to provide risk exposure criteria thresholds and action limits for inhabitants and site entrants.

Prerequisites: The preliminary tasks to this effort will be defining the target materials to be sampled (TASK Target) and then "marry" with instruments/sensors: (1) Determine the credible contaminants of concern left in the site residue, (2) Determine contaminant targets and credible and scientifically defensible exposure level requirements for the CAR, and (3) From the above, determine the technically defensible boundaries of the CAR.

Estimated Duration: 48 months

Technology/Technique Descriptions

None identified

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[1] *AIHA 2001 Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook*, Fairfax, VA: American Industrial Hygience Association, 2001.

TARGET 3.3

Deploy a set of peer-reviewed safety system monitoring options and design aids for selecting and tailoring the monitoring subsystems for active and passive safety systems, to reduce capital and operations and maintenance costs by 40 percent during the first ten years of LTS, with anticipated increased savings during subsequent decades.

Capability Enhancement Pathway

1. Establish criteria for passive systems → 2. Benchmark other criteria → 3. Identify equipment requirements → 4. Develop maintenance requirements (hardware) → 5. Select portfolios → 6. Conduct Peer Review → 7. Assemble technology store → 8. Distribute to closure sites (DOE approval)

Pathway Task Descriptions

Task #1: Establish criteria for passive systems

Description: Establish criteria for passive systems.

1. Ensure that local governmental regulations can be applied to target contaminants to provide necessary occupational exposure protection. In the case of a non-federal steward, ensure that adequate criteria are in place. DOE criteria for Phase #4 (occupational exposure) will already be established and monitors will have already been deployed for requisite detection/sensitivity capabilities for identified occupational exposures. The “baton” must handed off to the steward to ensure that the necessary and appropriate occupational exposure levels are monitored.

2. Determine the sensitivity required for environmental sensors (passive) i.e., topographical changes, intrusion metrics, etc.

Expected Products/Results: Application methodology to provide necessary risk based sensors and monitors for the occupational/passive environment that are compliant with steward entity, i.e., city, county, other federal agencies, etc.

Prerequisites: Need to have identified the target contaminants and intrusion risks.

Estimated Duration: 1.5 months

Task #2: Benchmark other criteria

Description: Benchmark other criteria. In addition to criteria needed for public health exposures and passive systems, criteria are needed for determining intrusion scenarios. These include topographic changes to the surface caused by subsidence or erosion, and physical intrusions related to humans, plants, and animals. Developing criteria for different types of sites will enable stewards to know when action needs to be taken and when it doesn’t.

Expected Products/Results: In addition to the criteria required for occupational health exposure levels and detection technology, the non-radiological/chemical hazard exposure capabilities of the passive system envelope need to be developed. The other hazards that need to be monitored include, but are not limited to, intrusion through barriers (gates, fences, walls, etc.) and unanticipated changes in source term environments (e.g., topography, flora and fauna, moisture changes, etc.). The monitoring and sensing systems will be integrated into the Information Technology system and retrieval programs discussed under Capability 4.

Prerequisites: Baseline information regarding surface conditions for the near-term closure sites and the types of physical barriers planned for keeping intruders out will need to be known.

Estimated Duration: 1 month

Task # 3: Identify equipment requirements

Description: Identify equipment requirements.

Active & Passive Technology Store addresses criteria, requirements, implementation, maintenance, and environment. Fernald has (reportedly) 80% of this completed. The Fernald site may be used as pilot or test bed. Certified vendor data must be maintained, updated, and employed for all monitors and sensors.

All Passive systems are, for the most part available and ready to install after on-site vendor commissioning. The hardware will be sensitive and precise enough to detect all occupational target levels, and many of the chemical instruments and sensors will be of wireless construction thereby freeing up labor costs for sampling, analysis, and data validation. Some R&D will be required in the modification and re-tooling of instruments to ensure that the systems are compatible with the environments.

The sensors and monitors, if needed in the CAR, are not available to provide the anticipated sensitivity required for all identified targets. Some vendors have and are developing wireless systems with increased sensitivity and quality that can be employed. The units are being used for detection of specific environmental airborne levels of certain chemicals in industry. Recent discussions with commercial manufacturers indicate capabilities exist for some of the expected targets defined.

For the active system monitors and sensors, vendor performance criteria will need to be developed for some of the derived targets and some existing equipment may be required to return to vendor laboratory for re-tooling, design, and testing prior to being placed back into service. It is anticipated that the DOE will provide field applications engineering services to ensure that the monitors and sensors meet all of the established criteria.

Expected Products/Results: Sampling and monitoring detection, precision and assembly/interface criteria for non-occupational (active system) targets will take four months after preliminary requirements are completed.

Prerequisites: Preliminary to this task, the targets of concern for the passive threshold limits values and for the non-occupational (active system) populations within the CAR will need to be identified.

Estimated Duration: 3 months

Task #4: Develop Maintenance Requirements

Description: Develop maintenance requirements for the safety systems. These systems need to be reliable without costly maintenance. Requirements for reliability will define schedules for expected replacement parts and materials. Requirements for onsite presence for maintenance (e.g., to calibrate instrumentation) will define the need for safety systems to perform automated performance checks and remotely notify stewards when equipment and instrumentation failures are imminent. Requirements for ease of repair and replacement will ensure that safety systems can be repaired easily.

Expected Products/Results: Safety systems that will operate at minimal cost and at minimal failure rates; repair/replacement will be simple and not require highly trained people.

Estimated Duration: 1.5 months

Task #5: Select Portfolios

Description: Select portfolios of safety systems components. A finite number of options for each subsystem (air contaminant migration detection, water contaminant detection, intrusion detection, barrier integrity assessment, surface integrity assessment, and notification to steward/community at risk) will be selected for inclusion in the stewardship safety system portfolios. The selection will be based on the requirements and what industry thinks it can deliver. The Information Technology system will be linked to Capability 4.

Expected Products/Results: A draft list of technology options for each stewardship safety system subsystem.

Estimated Duration: 3 months

Task #6: Conduct Peer Review

Description: Conduct peer review of the stewardship safety system subsystems. Peers will review the draft list of selected technologies for each safety subsystem to determine if the list is efficient, effective, and comprehensive.

Expected Products/Results: The peer review will result in a confirmed/modified list of options for each safety system or subsystem.

Estimated Duration: 3 months

Task #7: Assemble Technology Store

Description: Assemble store of safety system technologies for near-term closure sites. Each site will be able to assemble its safety systems by selecting the most appropriate technology for each subsystem. An analogy comes from the DOD. If you need a weapon system, you go to the catalog and select the system that best meets your requirements; there is no time or money to develop something new.

Expected Products/Results: A catalog of proven, efficient and reliable technologies from which a site steward can build a stewardship safety system.

Prerequisites: Peer review must be done first.

Estimated Duration: 3 months

Task #8: Distribute Catalogue to Closure Sites

Description: Distribute catalog of technology options to closure sites.

Expected Products/Results: Sites will select and implement the technologies for their safety systems.

Prerequisites: All the previous steps plus the technologies need to be manufactured.

Estimated Duration: 3 months

Technology/Technique Descriptions

Deploy sensors/monitors/remote system hardware to sites.

Description: Sensors that can detect contaminants of concern or target contaminants, operate remotely, and require 40% less maintenance than presently employed in typically commercial waste remediation site or Brown-field mitigation projects. The reduction in maintenance costs would be reflected in the reduced labor costs for manually collecting, logging and shipping samples and the attendant costs associated with the quality assurance requirements associated with issuing the laboratory analysis. Further reductions in costs will be gained from the reduction of use of stationary laboratory analysis.

Current Maturity Level: Under Development

Range of Applicability: The technology should be applicable to all closure sites, for contaminants in soil (mechanically transmitted) and air. Upon completion, the units can be "commissioned" and they can then be tailored to be employed at all sites where needed and necessary. All that will be needed for this task is a deployment and procurement plan with the appropriate quality assurance requirements and certified vendor data.

Needed R&D: Industry vendors are doing their own R&D but likely are not working on sensors for all the stewardship target contaminants (yet to be determined), especially sensors that provide remote detection and signals and require significantly less maintenance and last for long periods. These sensors do not need to necessarily read absolutes, but rather detect and signal when thresholds of target contaminants are exceeded. Warning and or action levels will likely be provided within the instrument specification for detection criteria. The estimated duration of R&D is 1 month.

Provide sensors, monitors,alarms and consistent & effective barriers.

Description: Develop and provide the array of monitors and sensors needed to remotely detect breaks in the integrity of site boundaries which contains the source term of residue.

Current Maturity Level: Under development

Range of Applicability: The technology should be available and applicable to all closure sites, for contaminants in groundwater, soils, and air.

Needed R&D: None documented

Provide intrusion detectors and site barriers

Description: Develop and provide intrusion detectors and site barrier systems on site boundaries and source terms. Include systems for intrusion detection to detect movement in restricted areas.

Current Maturity Level: Being applied

Range of Applicability: The technology should be applicable to all closure sites, which contain residual contaminants, which can be contacted by mammals or insects (which can mechanically transport radionuclides at "detectable to concern" levels, such as fruitflies and termites) entering the boundary area.

Needed R&D: There are remote monitoring systems on the market (mostly video-type with some radio and microwave frequency signaling). These devices need to detect movement, changes in the biota and topography. They will operate remotely and record and signal credible or reportable events to a data interrogation system and provide signals in a retrievable database.

The technology, for all passive systems are developed, available, and being refined to become more rugged and long-lasting. All requirements, such as gates, fencing, intrusion detection, topographical and biotic change detectors, etc. are available and simply have to be adapted to the site environment before employment.

Defense in depth will need to be provided from the boundary to the source of residue material. Preliminary action: Insure that signals can be properly interrogated and will provide prompt response. Necessary action: Provide site specific Deployment Plan in passive system defense.

The choices from the array of available systems and components will be based upon a multiple of determinants to include the site environmental conditions and the size of the area to be protected. Estimated duration of research is 4 months.

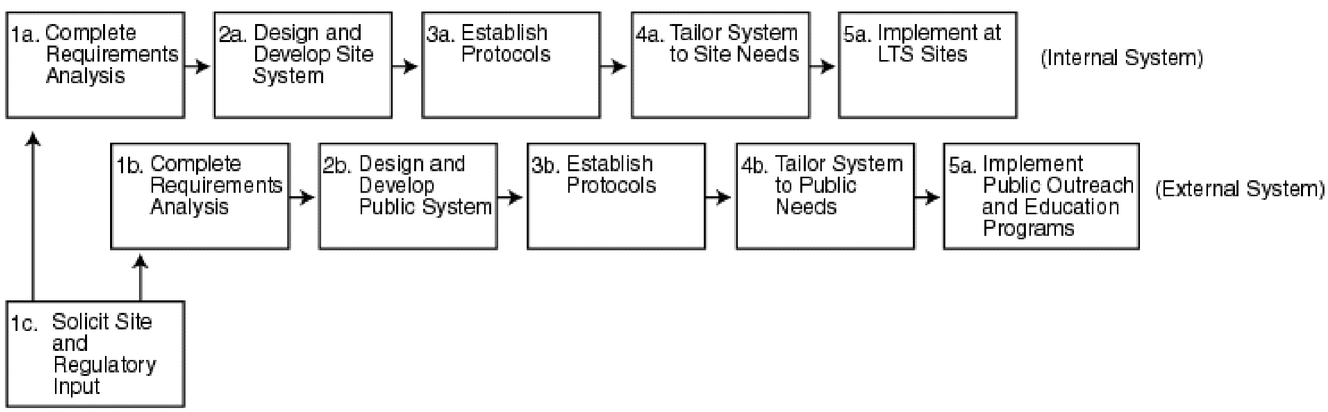
TARGET 4.1

Have in place at all DOE stewardship sites (and others working toward closure) a mature, functional, internet-based information management and communication system that is shared across the DOE complex. This system is to include two principal parts:

1. *An internal communications system designed to accommodate data storage, data validation, user access, and information visualization and dissemination, to be used primarily by site personnel for their internal communications and to facilitate communication with DOE headquarters staff and regulators*

2. *An external communications system that has both a public Internet site and other means of access for the public, facilitates public outreach and education, and fosters feedback and response from the public to site stewards.*

Capability Enhancement Pathway



Pathway Task Descriptions

The web-based Information Management and Communication Systems consist of two principle parts: 1) an **internal** communications system designed to accommodate data storage, data validation, user access, information dissemination, and visualization to be used primarily by site personnel and facilitate their communication with Headquarters and Regulators; and 2) an **external** communications system designed to facilitate Public Outreach and Education. The internal and external parts are of equal importance. The external communications portion (Public Outreach and Education) will be built upon the data storage, validation, and visualization capabilities of the internal system, and therefore must be developed subsequent to the development of the internal system.

The following sequence of tasks applies to development of the ***internal*** portion of the Information Management and Communication System.

Task #1A: Complete requirements analysis

Description: Complete a requirements analysis to guide the design of the Information Management and Communications System (internal). It is anticipated that establishing the Information Management and Communication System will be primarily a DOE Headquarters function, in that the systems established at all Long-Term Stewardship sites should be of comparable quality, layout, design, and performance. Communication with each of the involved sites, their regulatory agencies, and public advisory boards (1C), should be conducted to ensure that site-specific needs can be accommodated.

Expected Products/Results: Completion of a Requirements Analysis will identify the entire suite of site-specific issues that will need to be incorporated into the design of the complex-wide Information Management and Communication System.

Prerequisites: No prerequisites are considered necessary.

Eststimated Duration : 6 months

Task #2A: Design and develop information management and communication system for LTS sites

Description: Design and develop an idealized, generic, complex-wide information management and communication system, fully capable of storing and displaying environmental data and interpretations (raw field data, calculations, maps, conclusions, and projections).

Expected Products/Results: An Information Management and Communication System that is ready to be implemented at all Long-Term Stewardship sites across the complex.

Prerequisites: Completion of the Requirements Analysis (1A).

Eststimated Duration : 12 months

Task #3A: Establish protocols

Description: Establish protocols regarding data entry, usage, and user access.

Expected Products/Results: Following completion of the generic system design, protocols will need to be established that control and/or limit access to the data and other information contained in the system. It is assumed that site personnel and or program managers will have access to input and/or modify data, while others will be able to access information in a “read-only” format.

Prerequisites: Completion of the generic Information Management and Communication System (2A).

Eststimated Duration : 6 months

Task #4A: Tailor system to site needs

Description: Tailor generic information and management and communication system to accommodate site-specific needs.

Expected Products/Results: An Information Management and Communications System that is both compatible with the complex-wide DOE system and tailored to accommodate site-specific needs.

Prerequisites: Completion of the generic Information Management and Communication System (2A). It is also felt that, to some extent, Tasks 3A and 4A can be and should be completed at the same time, thereby minimizing the total amount of time necessary to develop and implement the system.

Eststimated Duration : 12 months

Task #5A: Implement system at LTS sites

Description: Implement the Information Management and Communication System at all Long-Term Stewardship sites.

Expected Products/Results: A functioning, web-based, upgradeable, complex-wide Information Management and Communication System, fully capable of storing and displaying environmental data and interpretations, that will facilitate effective management of the Long-Term Stewardship Program.

Prerequisites: Completion of the Information Management and Communication System tailored to meet site-specific needs (Task 4A).

Eststimated Duration: 6 months

The following sequence of tasks applies to development of the ***external*** portion of the Information Management and Communication System, which will consist primarily of Public Outreach and Education. The steps required to develop the Public Outreach and Education portion of the system will of necessity parallel the development of the internal portion of the system. Moreover, it is envisioned that the Information Management and Communication System developed for use by program managers at the sites will form the basis of the system to be used for Public Outreach and Education programs.

Task #1B: Complete Requirements Analysis

Description: Complete a requirements analysis to guide the design of the Public Outreach and Education portions of the Information Management and Communications System (external). It is anticipated that establishing the Information Management and Communication System will be primarily a DOE Headquarters function, in that the systems established at all Long-Term Stewardship sites should be of comparable quality, layout, design, and performance. Communication with each of the involved sites, their regulatory agencies, and public advisory boards (1C), should be conducted to ensure that site-specific needs can be accommodated.

Expected Products/Results: Completion of a Requirements Analysis will identify the entire suite of site-specific issues that will need to be incorporated into the design of the complex-wide Information Management and Communication System and facilitate development of Public Outreach and Education programs.

Prerequisites: No prerequisites are considered necessary.

Eststimated Duration : 6 months

Task #2B: Design and develop information management and communication system for Public

Description: Design and develop an idealized, generic, complex-wide Information Management and Communication System, fully capable of displaying environmental data and interpretations and supporting a Public Outreach and Education Program.

Expected Products/Results: A Public Outreach and Education Program that is ready to be implemented at all Long-Term Stewardship sites across the complex.

Prerequisites: Completion of the Requirements Analysis (1B).

Eststimated Duration : 12 months

Task #3B: Establish Protocols

Description: Establish protocols regarding data entry, usage, and user access.

Expected Products/Results: Following completion of the generic system design, protocols will need to be established that control and/or limit access to the data and other information contained in the system. It is assumed that, for the purpose of Public Outreach and Education, users will be able to access and manipulate information in a "read-only" format.

Prerequisites: Completion of the generic Information Management and Communication System (2B).

Eststimated Duration : 6 months

Task #4B: Tailor system to public needs

Description: Tailor generic Public Outreach and Education Program to accommodate site-specific needs.

Expected Products/Results: A Public Outreach and Education Program that is both compatible with the complex-wide DOE system and tailored to accommodate site-specific needs.

Prerequisites: Completion of the generic Information Management and Communication System (2B). It is also felt that, to some extent, Tasks 3B and 4B can be and should be completed at the same time, thereby minimizing the total amount of time necessary to develop and implement the system.

Eststimated Duration : 12 months

Task #5B: Implement public outreach and education program at LTS sites

Description: Implement the Public Outreach and Education Program at all Long-Term Stewardship sites.

Expected Products/Results: A functioning, web-based, upgradeable, complex-wide Public Outreach and Education Program, fully capable of storing and displaying environmental data and interpretations, that will facilitate effective communication of the Long-Term Stewardship Program to the public.

Prerequisites: Completion of the Information Management and Communication System tailored to meet site-specific needs (4B).

Eststimated Duration : 6 months

Task #1C: Solicit site and regulatory input

Description: Solicit Site and Regulatory input into the design of the system.

Expected Products/Results: Input from all Long-Term Stewardship sites and their regulators should be used to facilitate the development of the Information Management and Communications System.

Prerequisites: No prerequisites are considered necessary.

Eststimated Duration: 6 months

Technology/Technique Descriptions

None identified

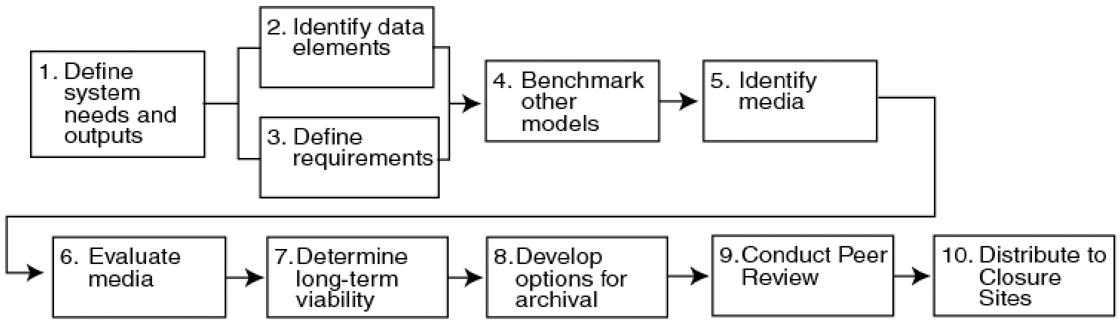
TARGET 4.2

The Roadmap team did not define an S&T target specifically for this enhancement. The S&T targets for Enhancements 4.1 and 6.5, if implemented as an integrated system, should suffice to provide this enhancement.

TARGET 4.3

Provide technology and information system options to enable stewardship sites to plan, implement, and maintain an efficient, optimized intergenerational archive. Include effective continuation of land-use controls among the objectives of these toolbox options.

Capability Enhancement Pathway



Pathway Task Descriptions

Task #1: Define system needs & outputs (obtain consensus)

<u>*Description:*</u> We must determine what the needs will be for future use, and preserve the information for easy access usage. The accessibility and clarity of information should be well known to the stewards for future use.

<u>*Expected Products/Results:*</u>

<u>*Estimated Duration:*</u> 6 months

Task #2: Identify Data Elements

<u>*Description:*</u> Identify Data Elements:

- Operational records
- Liability issues
- Closure data

<u>*Expected Products/Results:*</u> Understanding the efficiency and/or inefficiency to respond accordingly to meeting the needs of the stewards long-term.

<u>*Related Capability:*</u> Deploy optimal technology options for ensuring the preservation of site information from intergenerational technical continuity and reduce uncertainty.

<u>*Estimated Duration:*</u> 6 months

Task #3: Define Requirements

Expected Products/Results: The requirements will drive the outcome for long-term stewardship. If it is deemed critical to chose one methods over another, or one media over another, which will drive the success and/or failure.

Estimated Duration: 6 months

Task #4: Benchmark other models

Expected Products/Results: Each site will determine the process used towards records management. What will the site use for facilities, media, processes, methods, and required guidelines. The information gathered, each site must research the best guidelines that will be used by that site.

Estimated Duration: 6 months

Task #5: Identify Media

Expected Products/Results: The best media to date is paper and books. Consideration regarding labeling of field books, drawings, and other records, and documenting how records are created – particularly electronic records should be noted. The preservation of records and the type of media used depends on the information and its importance. The site can go to extremes and preserve information on available technology (i.e., micro fiche, acid paper, etc…). The determination has to be made by each site individually, especially when considering the impacting factors on the information being kept. The storage unit could be exposed to adverse conditions like weather, humidity, pests, and rodents. The type of media needs to reflect the region, and its conditions that will effect information preservation.

Estimated Duration: 3 months

Task #6: Evaluate Media

Expected Products/Results: We must be able to evaluate the effectiveness and ineffectiveness in the media used to preserve information. Responding to the inefficiency is critical.

Estimated Duration: 3 months

Task #7: Determine Long-term Viability

Expected Products/Results:

Estimated Duration: 3 months

Task #8: Develop Options for Archival

Expected Products/Results: Each site will determine the process used towards records management. What will the site use for facilities, media, processes, methods, and required guidelines. The information gathered, each site must research the best guidelines that will be used by that site.

Estimated Duration: 6 months

Task #9: Conduct Peer Review

Expected Products/Results: A peer review will help with the ownership and participation on preserving the managing of any records for the steward.

Estimated Duration: 6 months

Task #10: Distribute to Closure Sites

Expected Products/Results: Document how records were created and file accordingly.

Estimated Duration: 3 months

Technology/Technique Descriptions

Paper, Video, Micro Fiche, Digital, Photos

Current Maturity Level: mature

Range of Applicability: The technology should be applicable to all sites that require ongoing monitoring after closure.

Needed R&D: The processes and methods are available to the target capability. There is not universal method with regards to retaining records for stewardship that requires additional efforts beyond those typically used for DOE records. There is relatively inconsistent method of retaining information in a universal matter. The variation will make it challenging for future managers, operators, and scientists.

Symbols/Markers

Current Maturity Level: In development

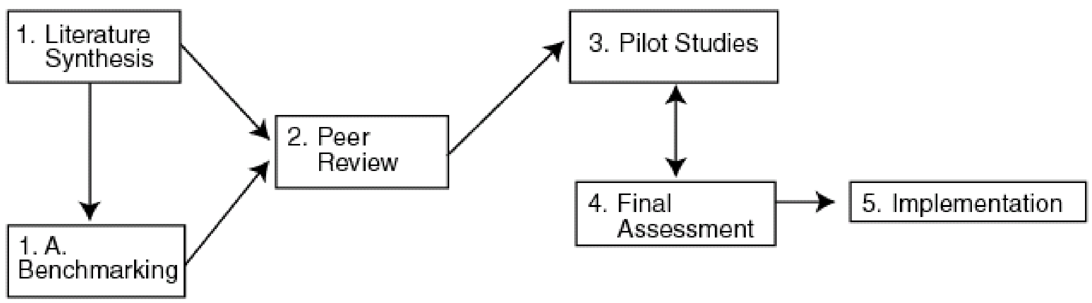
Range of Applicability: The technology should be applicable to all sites that require ongoing monitoring after closure.

Needed R&D:

TARGET 5.1

Finish case studies of agency actions that do or do not engender trust and confidence. Initiate full-scale field use of successful actions at selected sites.

Capability Enhancement Pathway



Pathway Task Descriptions

Tasks are divided into two sets: Knowledge generating tasks that gather and/or develop information on possible institutional mechanisms (Tasks 1, 1A, and 2); and process tasks that are needed to develop, periodically review, and modify, as needed, the mechanisms that have been selected for implementation (Tasks 3-5).

Task #1: Literature Synthesis

Description: Literature reviews to identify the most promising approaches (6-8 researchers)

Expected Products/Results: Initial identification of promising options with initial judgements of relevance of general guidance to specifics of DOE sites

Estimated Duration: 12 months

Task #1A: Initial Evaluation

Description: After 6 months, conduct benchmark "evaluation research" at selected sites; this will be the baseline study

Expected Products/Results: Initial testing or "ground truthing" of potentially promising options; refinements of initial expectations.

Estimated Duration: 6 months

Task #2: Peer Review

Description: Expert panel review (multi-discipline, include scholars from Europe, some from other industries, food processing, etc.) to pick the 5-6 most promising approaches, based on findings from Tasks 1 and 1A. Include DOE site managers and people from around the sites (site-specific advisory boards, intervention groups) - 2-3 meetings

Expected Products/Results: Peer-reviewed and vetted set of initial recommendations

Prerequisites: Advance approval of travel, especially for international experts, and sufficient high-level support form DOE to assure full participation by relevant DOE personnel

Estimated Duration: 6 months

Task #3: Pilot Studies

Description: Identify pilot studies (good match between approach and site-specific situation, buy-in by site manager) and conduct 2-3 pilots per approach (Consider UMTRA sites, when appropriate). Some may be combined trial of multiple approaches in one pilot. (Phase I - 12 months, expanded Phase II - 36 more months, after which results are institutionalized.)

Expected Products/Results: Actual data on relevance of Task 2 recommendations for specific DOE sites; at end of Phase 1. Improved ideas for further testing in Phase II

Prerequisites: Site manager buy-in

Estimated Duration: 48 months for both phases

Task #4: Final Assessment

Description: Assess pilot study results after completion of pilot phase

1. Site interviews, etc. Percentage of different perspective groups that are satisfied, etc. "evaluation research" - present results to Peer review panel. (Include more site managers) Produce report. Identify sites for initial full scale fielding. Include incentive funding for selected sites.

2. Meetings (early stage and final with site managers, etc.) Pay for people from the pilot sites to come and present - managers, CAB types, etc. Lots of time for informal interaction.

Expected Products/Results: Results that are needed for implementation in Task 5

Prerequisites: Findings from Task 3

Estimated Duration: 6 months (concurrent with start of Task 3 Phase II)

Task #5: Implementation

Description: Full-scale implementation

Expected Products/Results:

Prerequisites: Findings from Tasks 1-4

Estimated Duration: ongoing (6 months)

Technology/Technique Descriptions

Techniques for Knowledge Generation: scientific studies of values and risk perception

Description:

- Social scientific surveys
- Analytic literature reviews and syntheses
- Expert review panels
- Ethnographic research and comparative case studies
- Evaluation research
- Decision analysis
- Community involvement studies

Current Maturity Level: These techniques are highly developed and could be fielded easily with a modicum of support

Range of Applicability: The above techniques apply to all closure sites.

Needed R&D: Studies on institutional performance, reliability, and failure, and on relationships between organizations and communities need to be reviewed to determine applicability. Additional work also needed to assess relevance of broader findings under “real world” conditions at actual DOE/LTS sites.

Techniques for Process Development

Description:

- Enhanced outreach programs
- Improved two-way communication between DOE personnel and community
- Citizen monitors
- Worker committees/ worker input (for larger sites or sites where only part is in stewardship)
- Local technical training (vo-tech); employ community members

Current Maturity Level: Some have been used successfully in other venues; the applicability of all, for LTS sites, is to be determined

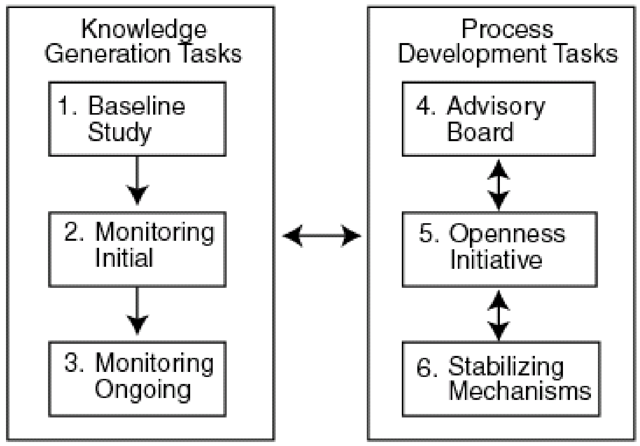
Range of Applicability: The above techniques apply to all closure sites.

Needed R&D: Studies on institutional performance, reliability, and failure, and on relationships between organizations and communities need to be reviewed to determine applicability at specific DOE/LTS sites.

TARGET 5.2

Identify lessons learned about public involvement and use them to design and implement techniques that align DOE and community objectives for stewardship.

Capability Enhancement Pathway



Pathway Task Descriptions

Tasks are divided here into two sets: those that serve to generate new knowledge (tasks 1-3) and those that serve to implement established processes (tasks 4-6).

Task #1: Obtain baseline data on community views

Description: Learn as much as possible about the values, beliefs, and interests of the community at issue, including (a) the perceptions of risk and (b) the sense of DOE credibility that obtain there, and incorporate that knowledge in every phase of the stewardship program.

Expected Products/Results: The first results of ethnographic research will be available within weeks of the initiation of the project, and will continue throughout its duration; the first wave of survey results should be available within a similar span of time; but all of the above are intended as ongoing sources of information.

Estimated Duration: 8 months

Task #2: Initial Monitoring

Description: Keep a trained scientific eye through all of the methods below above on changes that occur in the demographic composition or social character of the community so as to be able to modify stewardship arrangements when necessary.

Expected Products/Results: First semiannual report

Estimated Duration: 8 months

Task #3: Ongoing Monitoring

Description: Conduct regular program evaluations for the duration of the project and assure that mechanisms are in place for communicating their results to responsible DOE officials.

Expected Products/Results: Semiannual reports, providing ongoing feedback

Estimated Duration: Duration of study

Task #4: Advisory Board

Description: Agree on operation ground rules with community members representing the full range of community interests, and confer with those representatives on a regular basis as the work continues.

Phase 1: Ongoing coordination with tasks 1&2; 18 months
Phase 2: Ongoing coordination with task 3; duration of study

Expected Products/Results: Buy-in on ground rules, plus improved mutual understanding

Prerequisites: Agreement by community members as well as DOE officials to participate

Estimated Duration: Duration of study

Task #5: Openness Initiative

Description: Open channels of communication with relevant communities by acknowledging and accepting responsibility for past failures, both at the site in question and elsewhere; by making a special effort to explain how those failures came about, and to use that explanation as a basis for communicating the limitations under which DOE in particular and the federal government in general has to operate; and by enunciating as clearly as possible what values shape DOE policy. Special attention should be paid to information generated by task 1 above.

Expected Products/Results: Potential for improved credibility

Prerequisites: Agreement to participate on the part of relevant DOE officials

Estimated Duration: ongoing

Task #6: Establish and Maintain Stabilizing Mechanisms

Description: Establish and maintain mechanisms in the stewardship program that permit it to remain stable, predictable, and responsible over the long term and not sensitive to shifts in congressional mood, biannual elections, and the politics of the moment. We recognize that this will require a major shift in emphases.

Phase 1: Literature review and interviews; 12 months

Phase 2: Initial reports back to (a) community, (b) DOE officials, (c) broader science community; incorporation of feedback; 12 months

Phase 3: Preparation of final findings and recommendations; 10 months. Review and response to feedback; final 2 months

Expected Products/Results: Improved mechanisms for long-term performance

Estimated Duration: 36 months

Technology/Technique Descriptions

Techniques for Knowledge Generation

Description:

- ethnographic research
- survey research
- key-informant interviews
- continuing community panels
- evaluation research

Current Maturity Level: Methods are all reasonably well-developed; additional work will be needed to tailor the work to DOE/LTS needs.

Range of Applicability: The above techniques apply to all closure sites. In addition, information from the first sites involved should be made available to subsequent sites in the form of pilot studies

Needed R&D: All of the techniques necessary for the above tasks are well developed. Greatest need is for learning more about potential DOE roadblocks and other factors that might impede the development of the commitment and good-will that will be needed from those who are entrusted with the responsibility for carrying them out.

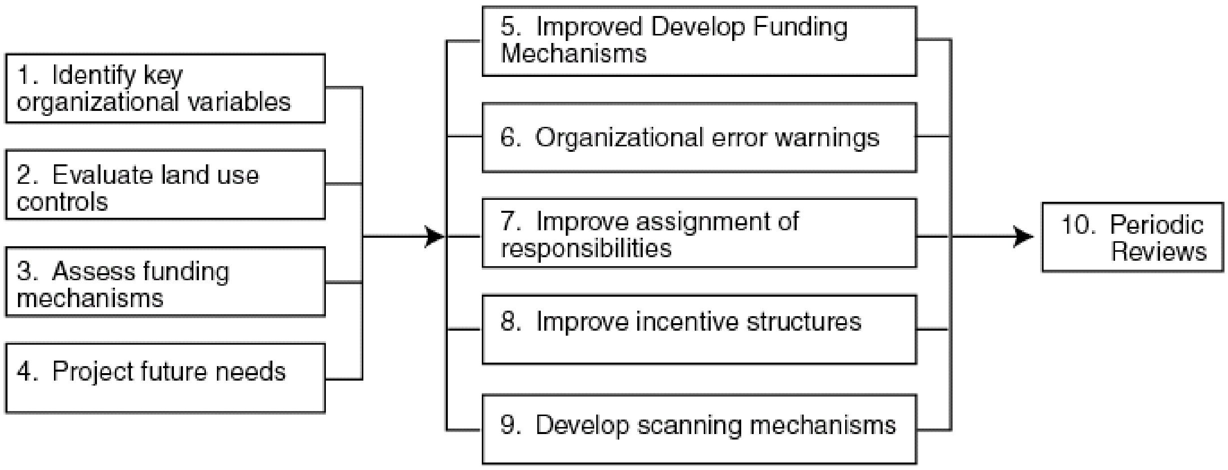
Techniques for Process Development

Description: Opening up lines of communication so that information gathered about the community is conveyed to DOE personnel and information about DOE policies and limitations is conveyed to the community

TARGET 5.3

Design and implement institutional mechanisms that sustain and improve LTS.

Capability Enhancement Pathway



Pathway Task Descriptions

Tasks are divided into two sets: Those that generate knowledge on possible institutional mechanisms (tasks 1-4); and those process tasks that are needed to develop, periodically review, and modify, as needed, the mechanisms that have been selected for implementation (tasks 5-10).

Task #1: Identify major forms or pathways of institutional failure and success

Description: Review and synthesize available findings on the failures and successes of institutional reliability and performance. Identify how and under what conditions these factors invluence organizations' ability to adapt to new knowledge and new circumstances regarding risk, science, and legitimacy associated with long-term stewardship. Assess the ways in which long-term stewardship may require organizational arrangements such as decentralized decision-making authority, specialization of functions among different organizational units, and Increased institutional permeability and transparency.

Expected Products/Results: Improved understanding of major factors influencing success and failure in stewardship organizations

Estimated Duration: 18 months

Task #2: Identify conditions under which physical and land use controls do or do not remain effective

Description: Build on ongoing evaluations (e.g. by ECMA, ELI, etc.) to understand the major factors contributing to the failure or success of land use controls at a variety of sites. Assess the allocation of authority and responsibility for monitoring, enforcing, and evaluating the performance of successful and failed land use controls.

Expected Products/Results: Improved ability to avoid reliance on forms of land use controls having known problems for LTS purposes.

Estimated Duration: 18 months

Task #3: Identify funding mechanism failures and successes

Description: Review and synthesize available literature on the strengths and weaknesses of mechanisms intended to provide sustained and adequate funding of long-term stewardship activities. Assess the objectives, structures, and effectiveness of possible mechanisms such as trust funds; federal organizations responsible for maintaining control and oversight of land and its uses; public enterprises; quasi-public organizations; insurance tools; and annual congressional appropriations.

Expected Products/Results: Response to understandable public concerns over reliability of assurances about long-term organizational constancy, and improved ability to carry out LTS responsibilities.

Estimated Duration: 18 months

Task #4: Learn what is known about social factors that influence risk through time

Description: To compile the existing knowledge of how conceptions of risk change through time. To assess the gaps in that knowledge and initiate studies to address them.

Expected Products/Results: Improved ability to anticipate future needs, and input to development of information archival systems.

Estimated Duration: 18 months

Task #5: Develop adequate and reliable funding mechanisms

Description: To identify existing mechanisms or develop new or hybrid mechanisms to provide adequate and reliable sources of LTS funding.

Expected Products/Results: Improved capacity for reliable long-term performance.

Prerequisites: Findings from Tasks 1-4

Estimated Duration: 1 year

Task #6: Develop "early warning"/near miss tracking and response system

Description: Development of improved indicators of factors that could presage LTS failure, and of realistic contingency plans. Improved ability to manage and communicate information about their own failures, as well as those of other organizations, so that organizational learning, adaptability, and resilience are enhanced.

Expected Products/Results: "Early warning" indicators of impending orgnaizational failure, to be used in conjunction with physical sensors and monitoring mechanisms.

Prerequisites: Findings from Tasks 1-4

Estimated Duration: 1 year

Task #7: Identify mission owners and roles and responsibilities of stewardship entities

Description: To establish the criteria and processes for establishing "ownership" of the LTS mission and how ownership changes through time. To delineate the roles and responsibilities of entities with LTS involvement. that, among other capabilities, decentralize decision making authority, require specialization of function among different organizational units, and feature appropriately permeable boundaries.

Expected Products/Results: Improved alignment between LTS needs and organizational capabilities

Prerequisites: Findings from Tasks 1-4

Estimated Duration: 1 year

Task #8: Develop appropriate organizational cultures with supporting incentive and sanction structures

Description: To develop organizational incentive structures that prize innovation, flexibility, creativity, and dissent in order to increase the range of alternatives for responding to problems as they arise. To develop organizational sanction structures that are clearly understood, commensurate with the effects of violations, and sufficiently robust.

Expected Products/Results: Increased ability to assure appropriate organizational performance over time

Prerequisites: Findings from Tasks 1-4

Estimated Duration: 1 year

Task #9: Develop mechanisms to ensure continuous scanning for social factors that influence risk through time

Description: To design and implement the methods necessary to identify, assess, and respond to social factors such as economic, demographic, political, and regulatory trends, and hazard averseness that influence conceptions of and reactions to risk.

Expected Products/Results: Improved monitoring of surrounding human environment

Prerequisites: Findings from Tasks 1-4

Estimated Duration: 1 year

Task #10: Develop and implement periodic review mechanisms

Description: To prepare and incorporate systems and methods to assess the performance of the LTS institutional mechanisms on an ongoing basis.

Expected Products/Results: Full-scale implementation of monitoring/early warning mechanisms developed in Tasks 5-9

Prerequisites: Findings from Tasks 1-4

Estimated Duration: 1 year

Technology/Technique Descriptions

Techniques for Knowledge Generation:

Description: Review of case studies, relevant documents, and other literature:

- Key-informant interviews;
- Exert review panels;
- Ethnographic and comparative case studies;
- Content analysis; and
- Analyses and synthesis.

Needed R&D: The techniques are well established but the state of knowledge as to what institutional mechanisms are effective for LTS is very immature.

Techniques for Process Development

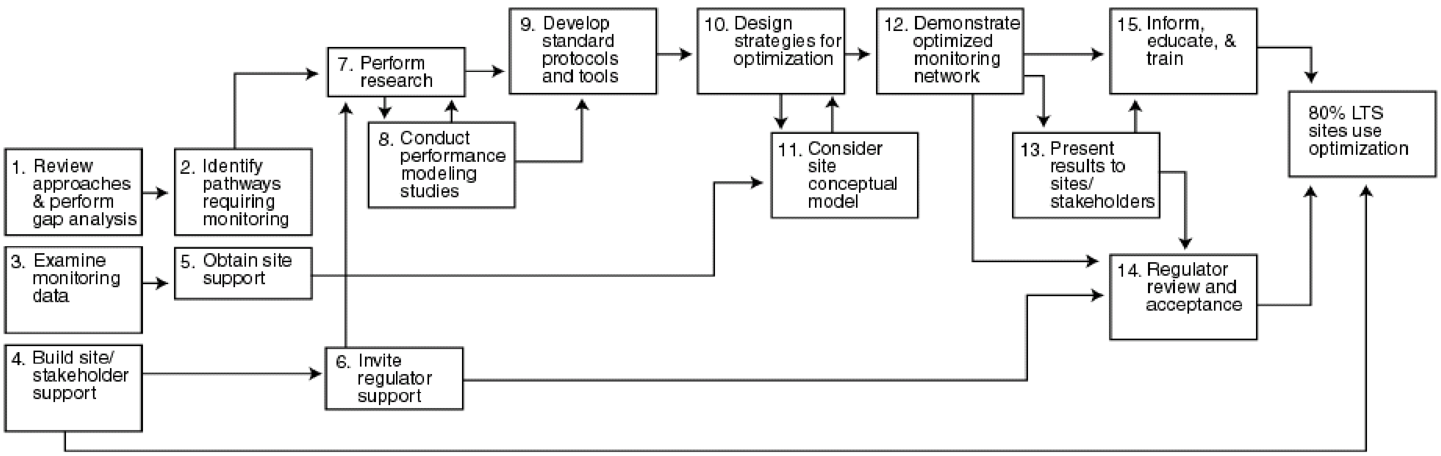
Description: Involving LTS managers and others in evaluating options;

- Involving LTS managers and others in conducting pilot studies;
- Involving LTS managers and others in full-scale implementation; and
- Conducting evaluation research on the tasks products.

TARGET 6.1A

Eighty percent of DOE sites going to closure and stewardship use a monitoring system optimization strategy.

Capability Enhancement Pathway



Pathway Task Descriptions

Task #1: Review and inventory existing approaches and perform gap analysis for all pathways

Description: Review literature on approaches to design of optimal monitoring systems for each pathway. This includes EPA, DOE and DOD reports and lists. Identify gaps

Expected Products/Results: Report that describes current approaches for various pathways and gap analysis to focus R&D efforts.

Prerequisites: None

Estimated Duration: 9 months

Task # 2 Identify media that require monitoring at LTS sites

Description: For each LTS site, identify various pathways that will require monitoring system. This will include building and other man-made structures. The process will use both interviews of site personnel and reviews of existing documentation.

Expected Products/Results: Report providing important pathways for each site. This report will focus R&D activities

Prerequisites: None

Estimated Duration: 6 months

Task # 3 Examine existing long-term monitoring data

Description: Data are available for most DOE sites from environmental surveillance and field experiments that can support monitoring system design. These data will be reviewed and analyzed to provide an initial basis for designing optimal monitoring systems.

Expected Products/Results: A database and report with results of data analysis to support optimal monitoring system design and guide R&D efforts for future work.

Prerequisites: None

Estimated Duration: 18 months

Task # 4 Build support for optimal monitoring systems among sites and stakeholders

Description: This task will present and explain the optimizing approach to users, the public and regulators so that its approach and assumptions are understood. This task will last the duration of the project, as interactions are necessary at times when information is available.

Expected Products/Results: _Reports on results of interactions and needed changes to protocols or research

Prerequisites: Optimized system is under development

Estimated Duration: 117 months

Task # 5 Obtain site input

Description: As optimized systems are developed, then input from site operators is needed on approaches, assumptions, and models.

Expected Products/Results: Report with feedback from sites on approaches that will direct further R&D.

Prerequisites: Information on site pathways (Task 2) and optimization approaches

Estimated Duration : 6 months

Task # 6 Invite regulator comment

Description: Regulators, both state and federal, will need to be informed of the optimal monitoring system approach and they can provide regulatory requirements in addition to expressing their concerns about the approach.

Expected Products/Results: Reports with regulator feedback so that R&D can be focused.

Prerequisites: Identify media at sites and optimal sampling approaches.

Estimated Duration: 6 months

Task # 7 Perform research based on gap analysis by media

Description: This task will perform research to address gaps. New or modified approaches will be developed for each pathway including building and other infrastructure. Bayesian methods will be developed to allow for updating of the sampling scheme and conceptual model.

Expected Products/Results: Technologies, including software, will be developed to support design of optimized monitoring networks by media.

Prerequisites: Review of existing approaches and gap analysis (Task 1) site information (Task 2)

Estimated Duration: 36 months

Task # 8 Modeling studies

Description: Initial studies of effectiveness of optimized monitoring systems will be performed using modeling or synthetic studies. Various cases will be used to test the optimization algorithm by providing a subset or sampled data component and evaluate the performance of the optimization approach. Comparisons with an actual model generated field will provide the basis for the tests.

Expected Products/Results: Report on effectiveness of optimization approach with feedback to R&D tasks on improvements in performance needed. Initial; demonstration of cost effectiveness and regulatory acceptance.

Prerequisites: R&D to develop optimization algorithm (Task 7)

Estimated Duration : 18 months

Task # 9 Develop Standard Protocols and Tools

Description: For each optimization algorithm, a tool will be developed for field application. The tool will have a user interface and be checked for quality assurance. A guide or manual to apply the code will be developed.

Expected Products/Results: A set of computer codes, procedures and user's manuals will be generated.

Prerequisites: Optimization tools that have been developed, tested and are ready for field application.

Estimated Duration: 12 months

Task # 10 Design site specific strategies for optimization

Description: Work with sites to implement optimization tools. Identify requirements and media. Interact with site personnel and regulators.

Expected Products/Results: An optimized monitoring network for a given LTS will be generated.

Prerequisites: Complete optimization tools tests. Site conceptual model.

Estimated Duration: 12 months

Task # 11 Consider site conceptual model

Description: The design of an optimized monitoring network will require a conceptual model for the sampled pathways. This task will work with site personnel to obtain the most recent conceptual model.

Expected Products/Results: Report defining site conceptual model and parameter values to support design of optimized network.

Prerequisites: Optimized monitoring network protocol. Selected site.

Estimated Duration: 6 months

Task # 12 Demonstrate optimized monitoring network

Description: Implement the selected design at LTS sites. Site personnel will do data collection and management. Analysis of monitoring system performance and tests of monitoring system using tracers will be performed. Calibrate monitoring system, as data are available.

Expected Products/Results: Report providing results of test and monitoring system performance.

Prerequisites: Monitoring system installed.

Estimated Duration: 24 months

Task # 13 Present data and beneficial impacts

Description: Analyze performance of optimized system by comparing to other designs such as grid or judgment based approaches. Present results of analysis to site operators, regulators and public by providing cost figures, technical effectiveness and regulatory requirements.

Expected Products/Results: Report and presentations providing details on how systems performs and meets requirements.

Prerequisites: Demonstration data set and regulatory requirements.

Estimated Duration: 6 months

Task # _14_Regulator review and acceptance

Description: Review with regulator the performance of optimized monitoring system to insure that requirements are met and system is acceptable.

Expected Products/Results: Letter from regulator or administrative authority accepting optimized system and approach for site monitoring.

Prerequisites: Data from demonstration.

Estimated Duration: 12 months

Task # 15 Market, educate and train sites

Description: Provide information on cost savings and technical effectiveness of optimized monitoring network for marketing purposes. Train site personnel on approach and tools. Educate public and stakeholders on advantages and disadvantages of system.

Expected Products/Results: Software and manuals for use, training records, and site acceptance and implementation of approach.

Prerequisites: Completed tools and regulatory acceptance. Results of cost analyses.

Estimated Duration: 18 months

Technology/Technique Descriptions

Groundwater monitoring networks

Current Maturity Level: Under development

Range of Applicability: Conceptual model needed to describe flowpaths, knowledge of contaminant behavior (DNAPLs) needed, and vadose zone is included in this technology

Needed R&D: Subgrid variability impacts on parameter scaling, uncertainty analyses that includes both model and data errors, Bayesian approaches to optimal network design, coherent design with other pathways

Surface water monitoring

Current Maturity Level: Being applied

Range of Applicability: Information needed for water balance and erosion of surface cover, pedogenesis effects on long-term behavior

Needed R&D: The effects of uncertainty on network design, scale dependency of parameters, coherent network design with other pathways

Atmospheric monitoring network

Current Maturity Level: Being applied

Range of Applicability: Information on particulate, vapor and aerosols at a site, applications in complex terrain

Needed R&D: Local high-resolution models for network design, coherent network design with other pathways, approaches for manmade structures

Biological monitoring system

Current Maturity Level: In research

Range of Applicability: Primarily field sampling and inspection

Needed R&D: Develop remote sensing techniques, coherent network design with other pathways

Adaptive sampling

Current Maturity Level: Immature

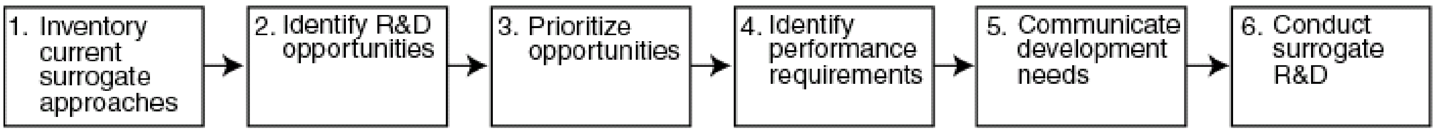
Range of Applicability: All sites using available information to change sampling to measure locations or frequencies that are most critical

Needed R&D: Data assimilation techniques that provide information to make sampling adjustments, real time data visualization and analysis capabilities

TARGET 6.1B

By 2008, half of DOE sites—and by 2010, all DOE sites—in stewardship or moving toward it plan to use contaminant surrogates and/or indicators in their LTS monitoring systems.

Capability Enhancement Pathway



Pathway Task Descriptions

Task #1: Inventory current approaches to the use of surrogates for all pathways

Description: Collection and study of existing approaches utilizing surrogates for monitoring air, surface water, vadose zone, groundwater, and manmade structures. Information can likely be initially obtained by performing research on the Internet and looking at the peer-reviewed literature. This information will be analyzed to determine costs, performance, and constraints on deployment for the various approaches currently being utilized.

Expected Products/Results: Report detailing current approaches, including an analysis of performance and costs for each method.

Prerequisites: Access to the Internet and peer-reviewed literature

Estimated Duration: 2 months

Task #2: Identify Opportunities

Description: Based on site and regulatory input, identify opportunities for research and demonstration of new surrogates.

Expected Products/Results: Report identifying R&D opportunities for surrogate parameters

Prerequisites: Inventory of current methods for surrogate analyses and access to DOE sites and regulators to obtain feedback

Estimated Duration: 4 months

Task #3: Prioritize opportunities by cost/risk/uncertainty

Description: Use cost and application data from task #1 with the opportunities identified in task 2 to rank opportunities for development or upgrading. The prioritization will be based on reduction of cost, risk, and uncertainty

Expected Products/Results: List of prioritized R&D opportunities by cost/risk/uncertainty for different sites and time

Prerequisites: Cost results from task #1, opportunities from task #2, information on risk and uncertainty related to these parameters for the different sites.

Estimated Duration: 1 month

Task #4 Identify performance requirements

Description: Define the metrics and capabilities that are the targets for the surrogate analyses. Critical input from regulatory staff will be required to ensure that they are comfortable with the demonstration of new approaches and have provided input as to performance requirements.

Expected Products/Results: Performance criteria for upgraded or newly developed methods or approaches

Prerequisites: Results from tasks #1, 2, and 3.

Estimated Duration: 2 months

Task #5: Develop compelling document for surrogate technology development

Description: Produce a white paper describing the inventory of existing techniques, the gap analysis, the prioritization, performance requirements for newly developed methods. Initial analysis of the costs, uncertainty, and risk benefits will be included. In addition, a short succinct presentation that portrays the important aspects of all these components will be developed and disseminated.

Expected Products/Results: White paper and short presentation

Prerequisites: Results from tasks #1, 2, 3, and 4

Estimated Duration: 2 months

Task #6: Conduct surrogate research and development

Description: Prepare a targeted call for proposals and select projects focused on identification and testing of a minimum of five new surrogates that meet the requirements of Tasks 4 and 5. Review and select proposals for funding. Track R&D.

Expected Products/Results: Proven surrogates that can be proposed to the regulators for long-term stewardship of a site

Prerequisites: Results from tasks #1, 2, 3, and 4

Expected Duration: 5 years

Technology/Technique Descriptions

Analytical Surrogates

Current Maturity Level: Under development

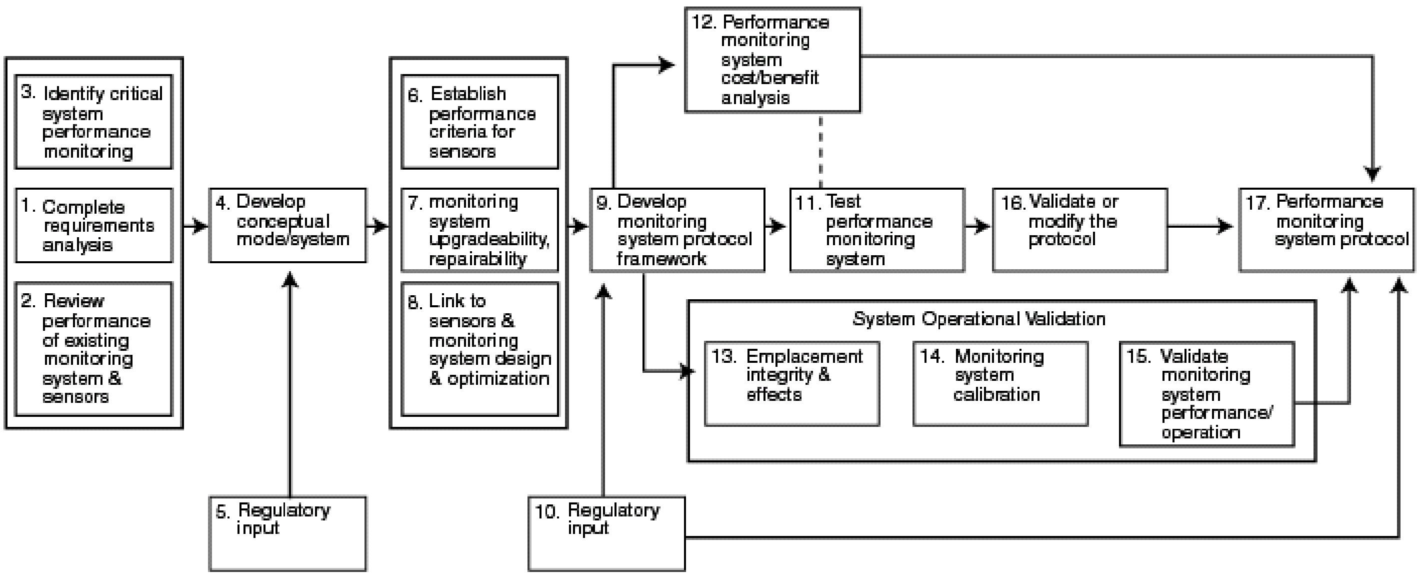
Range of Applicability: Can be used for optimization of all monitoring systems to meet LTS needs.

Needed R&D: Identification and testing of surrogates to reduce the number of sampling parameters is highly desirable. The performance of the surrogates as trackers of the high-risk contaminants must be validated and stakeholder acceptance must be obtained.

TARGET 6.2

Provide tools to verify CC&C system and contamination monitoring system performance.

Capability Enhancement Pathway



Pathway Task Descriptions

System Performance Requirements Assessment

Task #1: Complete Requirements Analysis

Description: Collect information on remedial system performance impacting compliance to remedial goal and objectives. Information should span the following categories; regulatory – stakeholder requirements and expectations, remedial system life-cycle processes, contaminant – waste layer interaction cycle with the remedial system, multimedia interfaces, and performance monitoring system deployment objectives and transition to stewardship. Assess the information collected to bound system performance requirements.

Expected Product/Result: Report detailing the information category assessment results, identify supporting information categories and technical requirements, highlight information/requirement gaps, and formulate bounded system performance requirements to transition to stewardship.

Prerequisites: Information on remedial system designs and formulation, and regulatory – stakeholder requirements and expectations.

Estimated Duration: 6 months

Task #2: Review Performance Existing Monitoring Systems and Sensors

Description: Collect information on existing remedial monitoring systems configurations and performance, and deployed sensor arrays. The information should address the following -- sensor performance and sensitivity, sensor data interface and quality, sensor durability and hardening, monitoring system integration process into the remedial design, and monitoring system deployment and installation sequence.

Supporting information as to selection of monitoring parameters and media interface, performance monitoring data processing and evaluation, and operational cost and lesson learned will be collected.

Expected Product/Result: Report benchmarking current performance monitoring system applications and formulating a monitoring system matrix depicting monitoring parameters cross referencing to applicable existing sensors, operational cost, data output quality and evaluation process, monitoring system & sensor bounding conditions, and identify monitoring system integration considerations/inputs to the remedial system design.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 12 months

Task #3: Identify Critical Performance Monitoring System Parameters

Description: In parallel with Tasks #1 & 2, categorize monitoring parameters regarding remedial system life-cycle short-term and long-term consideration, identify parametric bounding conditions regarding media and media interface, system/component failure events, and assess monitoring parametric value influencing risk management decision process.

Expected Product/Result: Report detailing the methodology of determining critical performance monitoring parameters and formulate a matrix of common performance monitoring parameters cross-referenced to media and bounding conditions based on remedial system application/configuration.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 6 months

Task #4: Develop Conceptual Model/Monitoring System

Description: Based on the information collected, develop conceptual monitoring system configurations based on remedial system applications. The conceptual monitoring system configuration will incorporate remedial system life-cycle processes and data evaluation methodologies to validate overall remedial system performance.

Expected Product/Result: Conceptual model depicting performance monitoring system configurations based on remedial system applications.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 6 months

Task #5: Regulatory Input for Conceptual Model

Description: Regulatory input and review of the task development and supporting task in formulating the conceptual model depicting performance monitoring system configurations based on remedial system applications.

Expected Product/Result: Regulatory concurrence with conceptual model for performance monitoring system configurations based on remedial system applications.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 3 months

System & Performance Definition

Task #6: Establish Performance Criteria for Success for Sensors

Description: Utilizing the Conceptual Model results (Task #4) and results from System Performance Requirements Assessment (Tasks # 1 – 3), develop criteria for success methodology for selecting appropriate sensor to address monitoring system requirements and bounding conditions based on the remedial system application. Attributes for sensor selection should touch the following areas – operability, deployment sequence and QC measures, data out-put and quality, reparability, upgradability, retreviability, and performance sustainability.

Expected Product/Result: Develop criteria for success methodology for selecting appropriate sensor.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 6 months

Task #7: Establish Performance Criteria for Success for Monitoring System

Description: Utilizing the Conceptual Model results (Task #4) and results from System Performance Requirements Assessment (Tasks # 1 – 3), develop criteria for success methodology for selecting an appropriate performance monitoring system. Attributes for monitoring system composition should touch the following areas – operability, deployment sequence and QC measures, sensor mix, data out-put and quality, reparability, upgradability, retreviability, and performance sustainability.

Expected Product/Result: Develop criteria for success methodology for selecting an appropriate performance monitoring system.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 6 months

Task #8: Linking Sensor & Monitoring System Design and Performance Optimization

Description: Utilizing the information complied in Tasks 6 & 7, identify system optimization points based on the remedial system life-cycle processes.

Expected Product/Result: Identify performance monitoring system optimization points.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 3 months

Task #9: Develop Performance Monitoring System Protocol – Framework

Description: Utilizing the information complied in Tasks 1 – 8, formulate the performance monitoring system protocol. This protocol provides the methodology to validate and the quality assurance means for the overall remedial system performance.

Expected Product/Result: Performance monitoring system protocol.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 12 months

Task #10: Regulatory Input for Performance Monitoring System Protocol

Description:: Regulatory input and review of the task development and supporting tasks in formulating the Performance Monitoring System Protocol.

Expected Product/Result: Regulatory concurrence with Performance Monitoring System Protocol.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 6 months

Task #11: Test Performance Monitoring System Protocol at a Closure Site

Description: Field Performance Monitoring System Protocol at a Closure Site – Rocky Flats, Fernald, Mound, or Astubula.

Expected Product/Result: Field Performance Monitoring System Protocol at a Closure Site by 2005. Optimal fielding scenario is to have at least two fielding in different regional climate settings. This effort would help bracket protocol results.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 6 months

Task #12: Performance Monitoring System Cost/Benefit Analysis

Description: Evaluate benefits and cost impacts for applying a performance monitoring system and validation sequence into a remedial design. The validation sequence is focused on providing the quality assurance measure of the overall remedial system in-place.

Expected Product/Result: Develop Performance Monitoring Cost Model

Prerequisites: See Development Pathway Diagram

Estimated Duration: 9 months

System Operational Validation

Task #13: Sensor and Monitoring System Emplacement Integrity & Effects

Description: Develop evaluation methodology to assess sensor/system emplacement and start-up sequencing for remedial system configurations and duration. The start-up sequencing provides the broadening factors to link point source measurement to aerial & volume measurements of the system. The evaluation methodology will incorporate non-invasive methods to discriminate sensor/system effects due to installation verses overall remedial system performance.

Expected Product/Result: Develop evaluation methodology to assess sensor/system emplacement and start-up sequencing.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 9 months

Task #14: Monitoring System Calibration

Description: Develop evaluation methodology to assess sensor/system emplacement and start-up calibration for performance monitoring system configurations. These affects are coupled to Task #13 results.

Expected Product/Result: Develop evaluation methodology to assess sensor/system emplacement and start-up calibration.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 9 months

Task #15: Validate Performance Monitoring System Operation & Remedial System Performance

Description: Operational fielding of the methodology developed in Tasks #13 & #14. Results from these effects are linked to Task #16 and system optimization activities.

Expected Product/Result: Operational fielding of the methodology developed in Tasks #13 & #14.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 9 months

Task #16: Validate/Modify the Protocol

Description: Operational fielding of the methodology developed in Tasks #12 - #15. Operational fielding should be focused on at least seasonal cycle and preferably two cycles to validate results. Regulatory input/interactions to concur with conclusions and/or modification based on field performance data (Tasks #11 - #15).

Expected Product/Result: Performance monitoring system data set to validate performance monitoring system application.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 36 months

Task #17: Performance Monitoring System Validation Protocol Fielding

Description: Consolidation from the results developed in Tasks #1 - #15 to establish boundary conditions and scaling factors for monitoring system application. Protocol framework provides the methodology for the remedial system designer to incorporate system validation measures. Regulatory review and approval/acceptance of the protocol is key to fielding.

Expected Product/Result: Performance monitoring system validation protocol for monitoring system application.

Prerequisites: See Development Pathway Diagram

Estimated Duration: 6 months

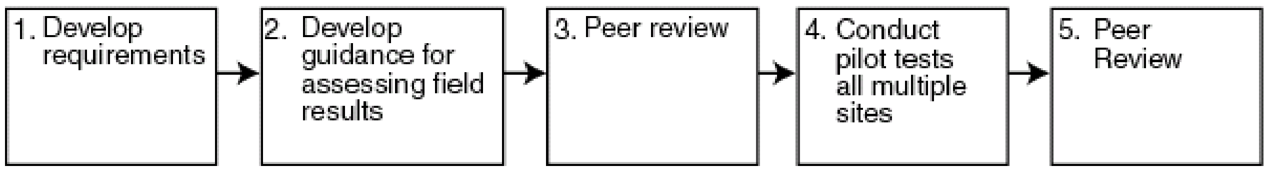
Technology/Technique Descriptions

None specifically identified.

TARGET 6.3

Provide tools to aid site stewards in verifying, monitoring, and periodically re-evaluating the technical and non-technical aspects of site safety system effectiveness.

Capability Enhancement Pathway



Pathway Task Descriptions

Task # 1: Develop requirements

Description: Develop performance assessment requirements. Determine action/regulatory levels for specific monitoring parameters.

Expected Products/Results: Design criteria. Manual. Data Dictionary.

Prerequisites: Monitoring parameters.

Estimated Duration: 6 months

Task # 2: Develop integrated feedback system

Description: Develop a feedback system (software package) that integrates all Safety System & Industrial Controls parameters being monitored for optimal effectiveness.

Expected Products/Results: Site specific, integrated data management system for SS&IC.

Prerequisites: Identify all safety systems and institutional controls that will be in place post-closure.

Estimated Duration: 6 months

Task # 3: Peer review

Description: Peer review of reassessment system involving impacted and appropriate stakeholders and experts to establish that model/software incorporates all applicable criteria and is user friendly.

Expected Products/Results: Validated re-assessment model with/for stakeholders.

Prerequisites: Identify affected stakeholders, experts in the field, and competent reviewers.

Estimated Duration: 3 months

Task # 4: Conduct pilot tests at multiple sites

Description: Pilot test the reassessment model at closure sites to make sure the system/software is adequate and incorporates changes as appropriate.

Expected Products/Results: Fully operational and implemented reassessment model that can be used as a template for other closure sites.

Prerequisites: Identify closure sites.

Estimated Duration: 36 months

Task # 5: Peer Review

Description: Peer review the pilot tested model for applicability and incorporation of relevant features for transfer of model/package to other closure sites.

Expected Products/Results: A complex-wide reassessment model/package/software for SS&IC.

Prerequisites: Identify other closure sites and appropriate peer reviewers.

Estimated Duration: 3 months

Technology/Technique Descriptions

Decision analysis

Description: Develop decision analysis tools to be used at closure sites.

Current Maturity Level: Being applied/Under development – There are existing systems/packages not directly appropriate to LTS, but could be adapted.

Range of Applicability: The technology should be applicable to all closure sites, for contaminants in the groundwater, soils, and air.

Needed R&D: Develop a system that integrates all components of SS&IC and determines/recommends appropriate action or mitigation necessary to assure continued, overall safety system performance.

Knowledge Management

Description: Develop knowledge management technology to be used at closure sites.

Current Maturity Level: Being applied/Under development – There are existing systems/packages not directly appropriate to LTS, but could be adapted.

Range of Applicability: The technology should be applicable to all closure sites, for contaminants in the groundwater, soils, and air.

Needed R&D: Software/communications package/plan, which disseminates relevant information to stakeholders and stewards informing them on status of system, how it is performing, and on any actions that may need to be resolved.

TARGET 6.4

Deploy technologies and protocols that significantly reduce the need for maintenance intervention of installed CC&C systems.

Capability Enhancement Pathway

Pathway Task Descriptions

To achieve this target, the LTS CC&C Workgroup consolidated the traditional waterfall model into the following technology development pathway:

Task #1: Review existing knowledge base.

Description: The traditional waterfall model steps of: concept and feasibility are included in this task. In the traditional model, concept is the step where you identify that you do not have the technology you need, or the technology that is available is inadequate. It is the realization that you are sub optimized in some way. This first task includes the following elements:

(a) Feasibility is a preliminary exploration of solutions that fit the physical processes (the physics of the problem).

(b) Some preliminary evaluation of costs and technical viability of alternate solutions is done.

(c) A review of the technologies available in the market place.

(d) An evaluation of the state of the development of applicable technologies is performed, along with some investigation of the availability of suppliers of such technology.

(e) An assessment of life-cycle requirements for support, maintenance, technological obsolescence, among other factors affecting life-cycle costs of a solution.

Expected Products/Results:

Expected Duration: 1 month

Task #2: Proof of concept – theoretical and bench scale.

Description: This step incorporates the traditional waterfall model steps of user definition of requirements, developer definition of requirements and high-level design. The proof of concept step contains the following elements:

(a) The user documents as much as he knows about the job the system must do. He may also specify schedule and cost constraints
(b) Special constraints, e.g. run on an specific platform; all supplementary requirements: documentation, maintenance, quality, standards

(c) Compliance, intermediate reviews
(d) Developer analyses of user requirement and performs further investigation of requirements, produces developers version of requirements
(e) Integration of developer and user system requirements document.
(f) Technology development plan
(g) Subsystem specification and design
(h) Cost, schedule analysis.

Expected Products/Results:

Expected Duration: 3 months)

Task #3: Site-specific treatability testing.

Description: This step incorporates the traditional waterfall model steps of prototype development and integration and test. This step includes the following elements:

(a) An initial working prototype is developed and made to work on a bench scale.
(b) Proof of principle is established in the general case
(c) Components and modules are brought together to form higher level systems.
(d) The bench scale process is tested against a specific user problem or scenario
(e) Scale-up issues are evaluated

Expected Products/Results:

Expected Duration: 8 months

Task #4: Pilot scale testing.

Description: This step incorporates the traditional waterfall model step of system test. This step includes the following elements:

(a) A fully integrated prototype system is developed and tested on a small scale
(b) System performance boundaries are explored, including failure modes (if practical)
(c) Maintenance and usability issues are explored
(d) Risk analysis

(e) Cost, schedule analysis.

Expected Products/Results:

Expected Duration: 1 year

Task #5: Deployment.

Description: This step incorporates the traditional waterfall model steps of systems test and part of acceptance test. This step includes the following elements:

(a) Full scale up of system
(b) Initial tests in actual end-user environment
(c) Exploration of actual full-scale end-user environment performance envelope.

(d) Exploration of usability, which may include such things as operator interface evaluation, health and safety, integration with other site systems
(e) Initiate process of system refinement
(f) Risk analysis
(g) Cost, schedule analysis.

Expected Products/Results:

Expected Duration: 1 year

Task #6: Monitor and validate field effectiveness.

Description: This step incorporates the traditional waterfall model of acceptance test (part of acceptance was accomplished in step 5) and operations. This step includes the following elements:

(a) Further exploration of usability, and performance envelope
(b) Continue system refinements
(c) Develop criteria and put a program in place to evaluation long-term system performance
(d) Further evaluate failure modes and their interaction with other site systems.

Expected Products/Results:

Expected Duration: 15 months

Task #7: Confidence building and institutional acceptance.

Description: This incorporates the traditional waterfall model of operations (part of operations was accomplished in step 6) and maintenance. This step includes the following elements:

(a) Institutionalizing the new technology
(b) Building acceptance of the new technology externally
(c) Defining long-term operability processes
(d) Defining failure mode prevention actions (preventative maintenance at the minimum)
(e) Defining long-term operations and maintenance costs
(f) Evaluation of useful life (replacement analysis)
(g) Risk analysis.

Expected Products/Results:

Expected Duration: 6 months

Technology/Technique Descriptions

Long-lived water treatment media

Description:

Current Maturity Level: The maturity level depends on the kind of water treatment is being done. For example, treatments needed for municipal supply of water are very mature. Problems of limited, special or complex nature, in groundwater are in the development phase. The water treatment media must be evaluated in the whole treatment system, including the regulatory aspects, transportation, disposal pathways, etc. For example, In some cases, longer lived water treatment media will mean the media will have a higher concentration of the contaminant, which may severely limit or prevent economic disposal options. Much research is going on in the formal term for this science, "separations".

Range of Applicability: All saturated zone applications involving in situ or ex situ water treatment.

Needed R&D: R&D needed is in the area of getters for contaminants that drive risk. For example, Tc99 is the risk driver for most DOE nuclear waste site, including Yucca Mtn.

Sources/ReSources:

http://www.nap.edu/html/groundwater_improving/
http://www.em.doe.gov/define/techs/rp-insit.html
http://www.epa.gov/ogwdw000/ars/treat.html
http://www.epa.gov/water/
http://www.wttac.unh.edu/
http://www.em.doe.gov/define/tables/t42.html
http://www.em.doe.gov/define/techs/techdes4.html#38
http://www.nmt.edu/mainpage/news/subsur.html
http://www.frtr.gov/optimization/singh.html
http://www.frtr.gov/optimization/streckfuss.html

Self-healing covers and caps. Alternatives to traditional caps and covers

Description:

Current Maturity Level: High for to RCRA subtitle C and D, low for alternatives (ET covers, graded covers, etc)

Range of Applicability: All climates and conditions.

Needed R&D: Most of the research is needed in the combination of alternative covers and caps and failure analysis. To design self-healing systems, we need to find out what the performance envelopes are for the alternatives (RCRA C and D are found to fail at a high rate, and failure modes are understood). We need to find out how alternative caps behave at the limits of environmental conditions and for acute events that may occur only on 100 – 1000 yr timeframes. We particularly lack long-term data sets on cap performance, or natural analogs. Development of synthetic materials, or identification of natural materials and their combinations that would enhance performance is a consequence of the R&D into alternatives and natural analogs and the failure mechanisms.

Sources/ReSources:

http://128.219.128.87/default.asp
http://www.em.doe.gov/rapic/9links.html

Grouts for in situ stabilization control

Description:

Current Maturity Level: Medium to High. Grouts are very advanced in applications in the mining, oil and water drilling/well completion areanas. Grouts for contaminant control and stabilization are not yet mature for EM applications.

Range of Applicability: Control of movement of contaminants in the subsurface, both saturated and vadose zones

Needed R&D: Emplacement, and verification of proper emplacement. Determination of final performance of grouts installed wet into the vadose zone (ultimate desiccation of materials). Performance and integrity confirmation of grouts, especially deep emplacements and where complex geometries are required.

Sources/Resources:

http://www.nap.edu/books/0309056853/html/
http://www.cmst.org/OTD/tech_summs/In_Situ_Rem/In_Situ_chap1.html
http://www.doegjpo.com/perm-barr/
http://www.rtdf.org/public/permbarr/default.htm
http://es.epa.gov/ncer_abstracts/centers/hsrc/biorem/eval.html
http://www.nwer.sandia.gov/wlp/capabilities.htm

In situ and ex situ regeneration of water treatment media

Description:

Current Maturity Level: Low to high: See technology technique # 1

Range of Applicability: All saturated zone applications involving in situ or ex situ water treatment.

Needed R&D:

Sources/ReSources:

http://www.groundwatersystems.com/bioprimr.html
http://www.frtr.gov/optimization/optimize.html
http://www.engg.ksu.edu/HSRC/97abstracts/doc72.html
http://www.dial.msstate.edu/monthlies/feb01.html

In situ flushing of leachate collection piping/trenches

Description:

Current Maturity Level: High for industrial-like leachate collection systems. Low for trenches, other non-pipe like transfer systems

Range of Applicability: Engineered disposal facilities

Needed R&D: For industrial-like collection systems, testing and possible modification of commercial systems. For trenches, and other non-pipe like structures, research into fouling mechanisms and design of facilities to facilitate regeneration.

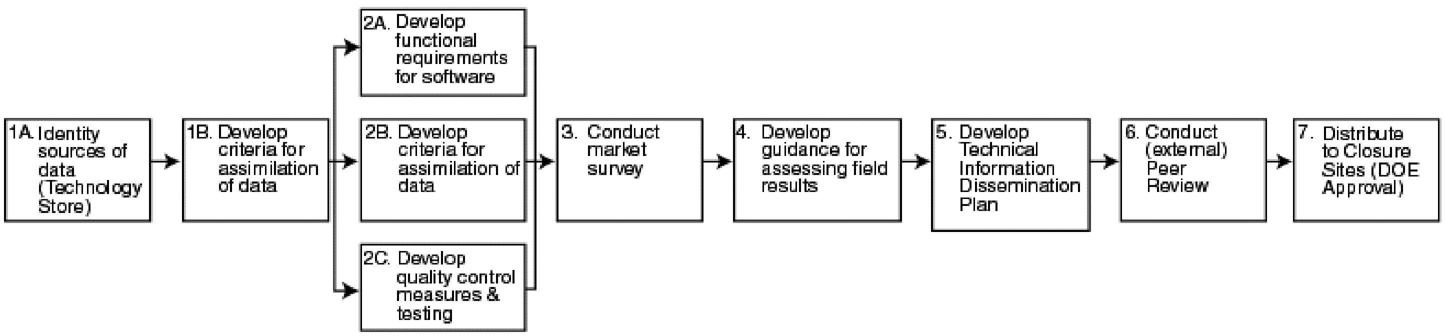
Sources/ReSources:

http://www.hcet.fiu.edu/r&d/tfa/unplugging/default.asp

TARGET 6.5

Issue action criteria for collecting, analyzing, and evaluating representative data on security and exposure systems, to reduce cost by 60 percent.

Capability Enhancement Pathway



Pathway Task Descriptions

Task # 1A: Identify sources of data & Task# 1B: Develop criterial for assimilation of data

Description:

Task 1A: Identify sources of data that will be collected and analyzed.

This would include data generated by active and passive monitoring systems. A closed site (or a site designated for near term closure) will be selected to develop templates that can then be applied to aid in the planning for security and exposure systems data collection, analysis and evaluation at other sites.

Task 1B: Develop the criteria for assimilating the data.

It is estimated that one person could complete these subtasks for a designated site in a period of three months. The subtasks involve determining the applicability of various data elements relative to passive monitoring of a site's physical condition. The data elements are generated by deployed technologies that were selected and installed prior to the site's closure. Since the data elements are known, the level of effort required during these initial subtasks is small.

Expected Products/Results: A matrix of data attributes that will be collected and analyzed for the demonstration site should be prepared. The matrix should identify a graded approach (e.g. chronic versus acute) for evaluating and acting on the information represented by the data. It should serve as a template for other sites to use during planning for long term stewardship.

Prerequisites: The program must be funded and assigned to a sponsor. The technology store must be established. A site must be selected to demonstrate the applicability of the planned approach.

Estimated Duration: 3 months

Task # 2A: Develop functional requirements for software & Task 2B: Develop maintenance requirements & Task 2C: Develop quality control measures & testing

Description: This task consists of three subtasks. These subtasks can be performed in parallel. It is expected that there will be interaction among all three subtasks so iterations of a subtask may be required to establish the software requirements. Each of these subtasks will be developed for a designated site and will be written so that they can be used as a template for other sites.

Task 2A involves developing the functional requirements for the software.
Task 2B involves developing the software maintenance requirements.
Task 2C involves developing the quality control measures and testing protocols for the software.

These tasks represent the first opportunity for meaningful involvement of the stakeholders. It is expected that the established software requirements will include input from the stakeholders so that future changes to the final product can be minimized.

It is estimated that one full time equivalent can perform these subtasks in 6 to 12 months. The uncertainty is due to the unknown amount of revision required as a result of the stakeholder involvement.

Expected Products/Results: These subtasks are expected to establish measurable requirements for the software development effort. These requirements will establish the framework under which the software will be evaluated for acceptability. The requirements will be documented and traceable. Concurrence by the affected stakeholders will be obtained and differing professional opinions will be identified and resolved.

Prerequisites: Prior to initiating these subtasks, the project must have a clear definition of the expected deliverables.

Estimated Duration: 6-12 months

Task # 3: Conduct market survey

Description: This task consists of performing a market survey to determine the availability of commercial software products that may used or may be modified for use. The products offered by various firms will be evaluated for applicability.

Expected Products/Results: A report will be prepared to summarize the availability of applicable software, the cost of the software, the cost of modifying software for specialized application, and restrictions relative to using the software. If commercial software is not available, then the effort required to generate the software should be estimated.

Prerequisites: The needs and requirements of the software must be clearly defined and documented.

Estimated Duration: 2 months

Task # 4 Develop Guidance for assessing field results

Description: This task involves developing the guidance for assessing the field results. Depending on the information contained in the data, various actions may be required. These might include no-action other than data recording, response to the site to mitigate a circumstance, or notification of adverse trends.

Expected Products/Results: The guidance should establish a menu of actions required based on the potential adverse consequences as predicted by analyzing the data. This task will be developed for a designated site and will be written so it can be used as a template for other sites.

Prerequisites: The data collection systems and the information represented by the data elements must be understood so that they can be translated into appropriate actions.

Estimated Duration: 1 month

Task # 5: Develop "Technical information dissemination plan"

Description:: This task involves developing the technical information dissemination plan. The form of and amount of data to be disseminated needs to be tailored to the audience and to the final use of the data. The plan should specify the data format (e.g. threshold, trends, chart, tabular, etc.) and should provide for effective presentation of the data. Extraneous or meaningless data should be culled from the data presentation.

Expected Products/Results: A plan for effective dissemination of collected data to the various audiences including the local community, the regulators, and the entity responsible for the site's contents. The plan should provide for efficient dissemination, while minimizing extraneous information.

Prerequisites: The needs of the audience, the data collection systems and the information represented by the data elements must be understood so that an effective data dissemination plan can be developed.

Estimated Duration: 1 month

Task # 6 Conduct (external) peer review

Description: This task consists of the external peer reviews of the plans associated with demonstrating the data collection, analysis, evaluation, and dissemination at a designated site. It is expected that the various stakeholders will participate in the peer review effort.

Expected Products/Results: Written and verbal presentations will be made to various groups including the local community, the scientific community, the regulators, and the entity responsible for the funding the project. Comments received will be evaluated and resolved. The documentation will be revised as appropriate.

Prerequisites: Clear, concise documentation of the planned demonstration program must be prepared and printed. The peer group and the stakeholders must be identified.

Estimated Duration: 3 months

Task # 7: Distribute at Closure Sites (DOE approval)

Description: This task consists of distributing the guidance document to the applicable sites that will be involved in long term stewardship.

Expected Products/Results: A template that can be used to plan for and design a long term data management system including collecting and analyzing the data as well as evaluating and disseminating the data elements.

Prerequisites: All plans and documentation must be revised into final form.

Estimated Duration: 1 month

Technology/Technique Descriptions

Remote detection of site physical changes

Description: Technology to remotely detect physical changes at a closed site and to identify changes that could result in an adverse impact on the environment (change detection).

Current Maturity Level: Under Development – There are no known situations where closed sites are being passively evaluated for adverse intrusion by people, flora, and fauna or for naturally occurring changes at the site. Such evaluation technologies do exist but must be modified and demonstrated for the defined application.

Range of Applicability: The technology should be applicable to all sites that require ongoing monitoring after closure.

Needed R&D: Demonstrate the capability of fuzzy logic to sense changes in site monitoring characteristics, to initiate alarms and to generate summary reports of adverse trends.

Decision analysis for adverse conditions

Description: Technology to decide appropriate action needed (decision analysis) if the parameters of a closed site change to a potentially adverse condition.

Range of Applicability: The technology should be applicable to all sites that require ongoing monitoring after closure.

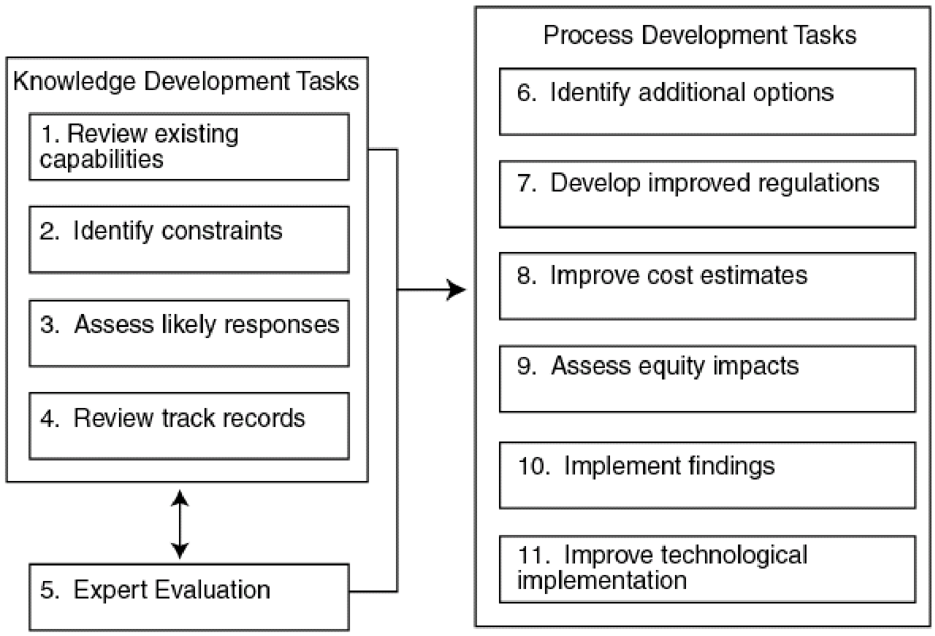
Current Maturity Level: Under Development – There are no known situations where closed sites are being passively evaluated for adverse intrusion by people, flora, and fauna or for naturally occurring changes at the site. Such evaluation technologies do exist but must be modified and demonstrated for the defined application.

Needed R&D: Develop software to monitor the various safety monitoring and intrusion detection devices, to analyze and differentiate among benign, chronic, and acute situations at a site, and to remotely communicate the site’s status to appropriate authorities.

TARGET 6.6

Provide tools to ensure the continuous review and improvement of LTS and cleanup decisions.

Capability Enhancement Pathway



Pathway Task Descriptions

Tasks have been grouped into two sets: those needed to generate the knowledge necessary to develop and implement the mechanisms that will ensure the periodic revisiting of LTS and cleanup decisions (Tasks 1-6); and those needed to develop, evaluate, and modify appropriate mechanisms to ensure periodic revisiting and improvement of LTS and cleanup decisions (Tasks 7-12).

Task #1: Review existing capabilities and drivers to revisit cleanup and LTS decisions and periodically ensure continuous improvement.

Description: To understand what legal drivers and mechanisms currently exist to ensure revisiting of cleanup and LTS decision, including but not limited to review of national law, state and local laws, and multi-agency cleanup agreements throughout the DOE weapons complex. To understand what capabilities exist currently to implement and to ensure continuous implementation of a review process. And, to understand what capabilities exist to ensure improvement of cleanup and LTS decisions. In all cases there will be an assessment of the strengths and weaknesses of current capabilities.

Expected Products/Results: Improved understanding of constraints to continuous improvement, and of steps that could be taken to respond

Estimated Duration: 2 years

Task #2: Review major constraints to institutional improvements.

Description: Multivariate analysis of factors identified as contributing to failure and success in institutions. Since LTS requirements may last a long time, enduring institutions, or mechanisms to ensure periodic revisiting of current decisions will be needed. It will be important to determine which institutional attributes should be encouraged and which should be avoided to establish an enduring review and improvement process.

Expected Products/Results: Improved ability to structure LTS organizations in ways that enhance rather than conflict with ongoing improvement.

Estimated Duration: 2 years

Task #3: Review possible alternatives to present conditions

Description: To understand how LTS institutions will weather and perform in a variety of conditions. Political, social, and economic conditions change. It will be important to gauge the ability of LTS institutions to continue and perform under a variety of conditions.

Expected Products/Results: More realistic understanding of likely long-term responses to societal changes

Estimated Duration: 2 years

Task #4: Review case studies showing established records of performance

Description: To understand what has worked and what has not thus far in the establishment and performance of enduring institutions, including the degree to which the original purpose is still served. Examples of institutions performing over a long period of time exist. It is important to determine what information can we glean from these examples in setting up LTS institutions.

Expected Products/Results: Improved understanding of "lessons to be learned" from past experiences

Estimated Duration: 2 years

Task #5: Workshop to evaluate reviews

Description: A workshop or series of workshops would evaluate information from the above reviews, and make recommendations for development of a robust system ensure periodic reviews and improvement of cleanup and LTS decisions. The workshops need to include specialists from appropriate disciplines and representatives from all affected parties, including DOE managers.

Expected Products/Results: Improved assurance of realism of findings and recommendations from Tasks 1-4, and development of "vetted" findings for inclusion into information archival systems.

Estimated Duration: 2 years

Task #6: Identify additional options for enduring institutions

Description Current knowledge about building enduring institutions is limited. More research will still be needed in this area, as will be the identification of new and more creative alternatives, including research into institutional success and failure, durability of legal structures, and public participation over long periods of time.

Expected Products/Results: Ongoing development of improved organizational performance

Estimated Duration: 3 years in two phases

Task #7: Develop a legal and regulatory structure

Description: There is no legal or regulatory structure that has been developed specifically to serve LTS needs. There are some provisions in existing laws and regulations that move toward periodic revisiting and improvement of site conditions (e.g. CERCLA). But even collectively, these provisions fall short. A comprehensive legal and regulatory structure that would require an periodic reassessment of all cleanup and LTS decisions (including a reassessment of institutional controls) is needed.

Expected Products/Results: Improved legal structures and provisions

Estimated Duration: 3 years in two phases 0

Task #8: Develop a cost mechanism that considers full life-cycle cost, including social cost

Description: Cost is a primary factor in decision making. Usually these are financial costs over a particular budget cycle. The impacts of incomplete cleanup of DOE weapons sites will have costs that stretch far beyond the typical budget cycle. Financial costs associated with maintaining engineered and institutional controls will stretch over long periods of time. Beyond financial costs directly related to maintaining safety at contaminated sites, there are costs to communities , financial and other, accrued as a result of hosting these contaminated sites. A mechanism to measure all costs to all sectors is needed to make the most prudent decisions about improvements to cleanup and LTS decisions.

Expected Products/Results: Ongoing improvements in understanding of long-term costs

Estimated Duration: 3 years in two phases

Task #9: Analyze equity impacts

Description: Decisions about changes to cleanup and LTS decisions will need to consider issues of equity: equity among regions; equity among generations; and equity among competing needs. An effective mechanism for such analysis needs to be developed and utilized.

Expected Products/Results: Improved understanding of equity concerns and impacts and of implications for public acceptability.

Estimated Duration: 3 years in two phases

Task #10: Implement an improved organizational structure of incentives and sanctions for robust periodic revisit and continuous improvement

Description: Organizations responsible for LTS will need to develop a system of rewards and sanctions that ensure that periodic revisiting happen in a robust manner. Monitoring cleanup and

LTS decisions runs the hazard of becoming a rote task, making particular attention to the development of regime of incentives and sanctions important. This regime will need to be revisited on a periodic basis to ensure that it remains robust.

Expected Products/Results: Full-scale Implementation of organizational improvements

Estimated Duration: 3 years in two phases

Task #11: Develop and implement an R&D program to force technology improvement

Description: Current decisions for limited cleanup are being driven in large part by limits of current technology to the job in a cost-effective and ecologically responsible manner. In the future, new technologies will need to be developed, but also implemented. Improved mechanisms for implementing the identified improvements will be necessary to ensure that LTS is carried out in a responsible and cost-effective manner.

Expected Products/Results: Improved ability to implement ongoing technological advances

Estimated Duration: 3 years in two phases

Technology/Technique Descriptions

Techniques for Knowledge Generation:

Description: The knowledge generation tasks are essentially techniques. Appropriate techniques for accomplishing the knowledge generation tasks include:

- literature review
- review of case studies
- key informant interviews
- expert evaluation of reviews and information gleaned from interviews
- stimulate research to support a robust ability to revisit cleanup and LTS decisions

Techniques for Process Development

Description: Appropriate techniques for the process development, evaluation, and feedback tasks include:

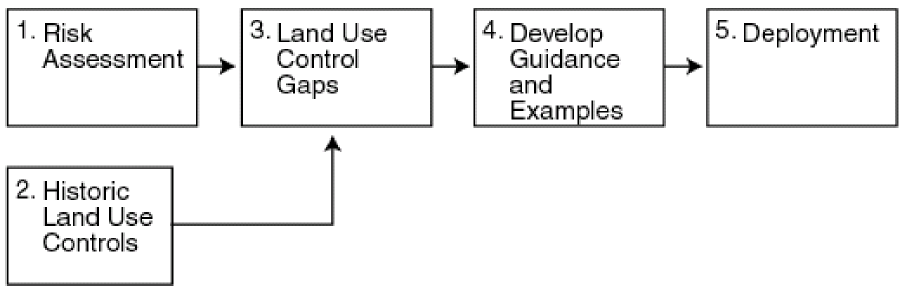
- working with stakeholders, legal specialists, economists, social scientists, public participation professional, stakeholders and appropriate agency personnel (regulatory and regulated) to develop necessary mechanisms.

- Conducting evaluation research on all task products.

TARGET 7.1

Provide options for potential legal strategies and associated instruments to facilitate handoff of closed sites to final steward(s).

Capability Enhancement Pathway



Pathway Task Descriptions

Task # 1 Risk Assessment

Description: A gap analysis will be conducted on 6 example communities at risk. The assessment will determine the breath and scope of institutional controls that have been incorporated at closed federal facilities. The sites will have to define "community at risk" (if required by the end state) in the template.

Expected Products/Results: Identification of institutional controls that are currently being implemented at various federal facilities and their effectiveness in achieving the requisite end state(s).

Estimated Duration: 3 months

Task # 2 Historical Land Use Controls

Description: A study of historical experiences with land use control will be conducted to develop lessons learned on what has worked and what hasn't (and why). Results will be summarized in "historical arguments" indicating where and why current legal instruments are non-optimal

Expected Products/Results: Historical arguments (past failures and successes).

Prerequisites: Identification of legal instruments needed in the future.

Estimated Duration: 3 months

Task # 3 Land Use Control Gaps

Description: An evaluation of existing land use institutional controls will be conducted. The evaluation will include identification of current control methods, development of a crosswalk of existing controls versus controls needed in the future, and identification of gaps needing either new legal instruments or modification of existing legal instruments.

Expected Products/Results: Crosswalk of existing versus needed new or proposed legal instruments (gap analysis).

Prerequisites: Identification of legal instruments needed in the future.

Estimated Duration: 6 months

Task # 4 Develop Guidance and Examples

Description: A land use institutional controls guidance document will be developed that indicates legal alternatives and the discriminating factors to be used in their selection. This task will include drafting of the document, inclusion of examples, peer review, incorporation of comments, and finalization of the document

Expected Products/Results: Final Systems Pathway Module for institutional control guidance document with examples and model documents.

Prerequisites: Crosswalk of existing versus needed legal instruments (gap analysis).

Estimated Duration: 9 months

Task # 5 Deployment

Description: Appropriate approvals and endorsements will be obtained for the land use control legal instruments guidance document. This includes approval by DOE and approval or endorsement by appropriate representation of local authorities expected to be involved with future LTS-related land use control issues (e.g. endorsement by the association of state governors).

Expected Products/Results: Systems Pathway Module Institutional Controls guidance document with examples approved and endorsed by DOE, the National Governors Association, and Environmental Council of the States (ECOS – a national non-profit, non-partisan association of state and territorial environmental commissioners).

Prerequisites: Final legal guidance document, Historical arguments

Estimated Duration: 24 months

Technology/Technique Descriptions

Development of a System Pathway Module.

Description: Development of a System Pathway Module. Module will have overall categories. State restrictions of exceptions will be noted, but this will be a general strategy.

Current Maturity Level:

Range of Applicability:

Needed R&D: Development of a System Pathway Module with specific examples of legal instruments and model documents that are legally and practically; such as, deeds of trust, reverters, restrictions, easements, negative easements, covenants or other servitudes that realize effective institutional control over a site in LTS.

TARGET 7.2

The Roadmap team did not define an S&T target specifically for this enhancement. The S&T targets for Enhancements 6.3, if implemented as an integrated system, should suffice to provide this enhancement.